MINING, LAND USE, AND THE ENVIRONMENT

I: A CANADIAN OVERVIEW

by

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Environment Canada

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LAND USE IN CANADA SERIES

The *Land Use in Canada Series* is designed to address major land-use issues and problems in Canada. The series, produced by and for the Lands Directorate of Environment Canada, examines the causes and consequences of major land problems and land-use trends throughout Canada and the role of various government programs in eliciting solutions.

Incorporating the earlier series entitled *Land Use Programs in Canada* which reviewed the land-use programs of Canada's ten provinces, the series examines, from a national perspective, activities affecting the use of Canada's land.

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PREFACE

The proper management and use of Canada's land resource is an issue of national concern. Earlier studies by the Lands Directorate such as *Canada's Special Resource Lands* have examined a number of the resource sectors including agriculture, forestry, recreation, wildlife, urban growth and energy development, but the mining sector has yet to be studied in depth. This report examines the nature and extent of the impact of the mining industry on the land resource. The specific purpose of this study is to provide a national overview of the scope of mining land use activities. These include the nature and extent of land degradation processes attributable to mining, their effects on neighbouring land resources, the potential for land use conflicts that may arise, and what progress has been made in the field of reclamation. By understanding how and why mining is one of the many competing uses of the land resource, better decisions on the management of the nation's land resource are posssible.

The Lands Directorate of Environment Canada is engaged in a continuing program of research into the causes and consequences of land problems and issues in Canada and the means by which they can be resolved. Through a better understanding of the demands for land, measures can be designed to influence its uses so that all Canadians will benefit from the wise use of their land resource.

R.J. McCormack
Director General
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NFB — Phototheque — ONF, Cliff Baskin

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INTRODUCTION

Man has always been conspicuous in his ability to alter the surface of the land for his own purposes. This alteration of the natural environment causes disturbance and changes the land use to varying degrees. Some of the most extreme alteration occurs in the search for, and eventual extraction, benificiation, and processing of, mineral and energy resources. The mining industry in the late 1960's, due to the nature of its extraction, processing, and waste-disposal practices, was undoubtedly subject to some of the most vigorous condemnation for causing highly visible environmental degradation.

PUBLIC PERCEPTION OF MINING

Canadian mining operations have been envisaged by environmentalists and conservationalists alike, as causing serious adverse problems, though primarily in the somewhat remote areas of the Shield, the North, the Maritimes, and in the Rockies. Undoubtedly, the operations of metal and coal producers have caused varying degrees of environmental damage in these areas. In the urban, suburban, and rural settings of agricultural communities, however, it is not the limited number of metal and coal producers, but rather the operators of the ubiquitous sand and gravel pits, rock quarries, and certain industrial mineral mines who have been considered as being the more visible and significant offenders. Moreover, much of the concern has been focused on the concurrent and subsequent physical and aesthetic effects which their operations have had on the land — as a basic resource. But, unlike most human activities, mining is only a temporary occupier of the land surface and, hence, is of a transient nature. Although, active mines at any point in time are not as widespread in comparison to other land uses, they dramatically change the landscape and tend to leave evidence of their past use. Thus, results of abandonment or closure become most conspicuous to the general public.

By the early 1970's, confrontations between citizens' groups, government agencies, and members of the mining industry had become commonplace. The degree of conflict and its nature usually depended on the current land use and the estimated consequences of proposed disturbances. The conflicts centred on issues involving destruction of the landscape, degradation of the visual environment, disturbance of water courses, destruction of agricultural and forest lands, damage to recreational lands, and native claims, in addition to noise, dust, truck traffic, and public nuisance, all of which are normally associated with various stages of mining.

Our environmental conscience has now developed dramatically and has led to a widespread belief that governments at all levels in Canada should be able to control the depletion of natural resources and excessive environmental damage. Public pressure has forced a considerable increase in government intervention to protect the environment through a wide range of controls aimed at reducing the impacts of major resource developments on the environment. Government intervention has also been required to alleviate public concern about land use conflicts in order to provide for adequate access to much needed future renewable and non-renewable resources.

UNIQUENESS OF MINING

LOCATION

Mineral deposits have fixed locations; they are where you find them. As a consequence, mining activities, unlike renewable resource activities — fishing, agriculture, and forestry — are not subject to rational selection or advanced planning. Due to the unique physical conditions associated with their location, there is no choice about the characteristics of their ecological setting, nor as to the physical and chemical characteristics, mineral composition, or grade of ore in question. All of these factors influence the ultimate design, layout, and size of the operation, as well as the basic

Coal Mining at Estevan, Saskatchewan, 1912
National Photography Collection, Public Archives Canada. PA38662

environmental problems which may arise at a particular mine site, and the potential larger range of regional impacts. The nature of the ecological setting will also determine other land uses or activities which would be affected by the proposed mining.

FINITE LIFE

Mines have a finite life. Because of the non-renewable nature of mineral deposits, mining is only a temporary land user. A mine may have a sporadic life of openings and closings due to market conditions, but eventually the deposits are depleted. In some situations, ore reserves are so great however, that mining activities appear to be a permanent fixture in the life of a region's inhabitants. Such is the case in the Sudbury region where, while individual mine sites come and go, the parent companies remain to plan and schedule the development of new mines from its widespread ore reserves.

ISOLATION

Canada's extremely large size, with its vast inhospitable and uninhabited spaces, has resulted in many resource developments being isolated. This is particularly evident in the mining industry where:

..."mines are usually located in a setting of relatively unspoiled nature. The contrast between the mine itself, its dump, mill and newly constructed town, and the wooded valley or otherwise unscarred mountain-side is always there for all to see. A generation ago, this isolated outpost of industry, winning wealth from untapped nature, was looked on as a symbol of man's ingenuity and as a proud demonstration of progress toward an ever expanding better future. Now it is looked on by some, perhaps by an increasing number, . . .as a forerunner of the destruction of the environment which supports us and of which we are a part." (Roots, 1977).

In many circumstances, the original mine is the very reason for a town's existence. It is only later that other means of economic support are generated. Often, because of the isolated nature of these mining towns in forested lake regions, alternative employment is found in forestry, recreation, and tourism. The latter two usually rely on increased access by a travelling public whose desire for a relatively clear, unspoiled environment contributes to changing view points and increased opposition to mining activities.

Parodoxically, this increased public access is the result of newly introduced mining and forestry operations.

The major difference between alternative land uses and mining in isolated forest, barren tundra, or alpine areas is that most alternative land uses are related to renewable resources, and are perceived as less damaging than mining, if properly managed. Similar perceptions exist for the less remote regions of Canada. For example mining activities are related to coal, sand, gravel, stone, and potash deposits underlying prime agricultural lands or bordering expanding urban centres. In these instances, however, the problem of land allocation is further compounded by political, social, economic, and environmental considerations.

The question is, "how can the mineral deposits be extracted in the short term without permanently altering the land values for post-mining uses?" Under these circumstances alternative land uses with a measurable economic value can present considerable competition for mineral-rich lands or can eventually lead to conflicts. In some cases, no matter how economically valuable a mineral deposit is, the socio-political factors in opposition are so strong that no new mine development will take place.

TIME LAG

Another important factor in mining is the effect of time, specifically "time lag". Despite the initial discovery and evaluation of a potential mine, there are years of development and construction before a mine begins production. Historical data, on metal mine openings between 1946 and 1971 in Canada indicate that the average time lag between discovery and initial production for all mines was six years (Dep. Energy, Mines and Resources, 1975). Some larger mines (50 to 100 million tons) took up to eight years. This time lag can have a considerable impact on the cost of financing and the ultimate return on investment once production starts. Time can also have an important effect on the ultimate impact of mining operations on the environment. Although most direct disturbances and effects can be anticipated, unforeseen physical and chemical changes to the environment can emerge at any stage in a mine's life or even long after closure, despite precautions. Each mine presents a unique set of planning and management problems during the development, production, and eventual closure stages.

CHANGING NATURE OF MINING

In the past decade, the legislation of new environmental controls and resource management procedures has resulted in a number of significant changes in the tradi-

Geco mine headframe, Manitouwadge, Ontario
NFB — Phototheque — ONF, Crombie McNeill

tional approach to both mining and resource development. The more significant of these measures include the following:

(i) Environmental impact assessment and Public Inquiries;
(ii) Conditions of "permit" approval;
(iii) Resource management and land use planning; and
(iv) Land reclamation and rehabilitation.

These controls have heightened the potential for a lengthy and complicated development process in the life of a future mine. In so doing, it has created the need for greater understanding between those used to traditional approaches to mining development and those advocating greater government control and public involvement in the process.

With a growing trend towards a more careful and formalized approach to proposals for all major resource developments, the use of Environmental Impact Assessment procedures as a guide to the development and management of a new project has been the method most widely adopted. Although the approach and requirements may vary between provinces and in the territories, its influence on mine development is similar. Throughout the development stage of a mine, two parallel processes are now essential: first, the engineering design, lay-out, and technological requirements normally associated with mine production; and secondly, a fully integrated environmental protection program that meets all existing regulations and standards for air, water, and land quality. Prospective operators must now collect environmental baseline data; conduct an environmental impact assessment and, increasingly, a parallel socio-economic impact assessment; and then proceed through a series of formal submissions, public hearings, and applications according to procedures established by the various provinces and territories.

In most cases, should approval to proceed with a mineral development be given, it is normal to impose constraints designed to reduce the environmental and/or socio-economic impacts. Usually the limitations or added protection requirements result from shortcomings in design or from concerns expressed in public hearings and technological assessments of the development proposals. Although the added requirements may not be found in existing regulations or standards, the "Permit Approval System" now allows for flexibility on a site-to-site or project-to-project

basis. Hence, final design and technological requirements for a mine site must wait for unforeseen changes that may emerge during the government assessment and public hearing stages of the formal evaluation procedures.

There is a growing need to be able to revise the conditions attached to a permit during the operational life of a mine, particularly when dealing with the control of air and water pollution. The life of a mine is frequently extended over several decades, during which time there can be significant unforeseen effects of mining activities, as well as technological and economic changes which affect the methods and quality of mining and pollution control. It is this unforeseen element that has heightened public concerns and increased the potential for opposition to many mining developments.

New mines are now responsible for the long-term use of the land, and hence, the need to prepare either for concurrent or sequential land use planning. So much of the ability to return mined land back into a viable post-mining use depends on the introduction of successful reclamation and rehabilitation techniques. Thus, reclamation requirements have become an essential component of environmental legislation pertaining to mines, especially with regard to long-term resource management and land use planning. However, in terms of practical application, this is not the case for all mines due to the relatively recent history of such legislation. Mines in operation prior to the establishment of environmental controls and post-mining land uses will be committed, in most cases, to the existing mine design and operations. Under these circumstances, reclamation and rehabilitation must be applied under more-difficult after-the-fact circumstances. It may prove to be exceedingly difficult, if not impossible, and a mutually agreeable compromise may be necessary, providing that all health and safety requirements are met. Not all provinces may require that reclamation be applied to activities prior to the establishment of reclamation legislation. In some cases, the responsibility has reverted to the provinces for mines closed or abandoned prior to the legislation. Not all mine operations are able to conduct concurrent or sequential land use planning. For example, in most metallic mines little evidence of reclamation or ultimate end use activities will be visible until the mine is in the post-mining stage.

Under some legislation, the use of certain designated lands will depend on the operating company's ability to show that it is feasible, or even probable in the near future, to successfully reclaim and rehabilitate the land to the government's designated post-mining use. Con-

Craigmont open-pit copper mine. Merritt, British Columbia
NFB — Phototheque — ONF, George Hunter

siderable research may be necessary before permit approval is forthcoming. The duration and scope of the mining process has been considerably altered. Reclamation must be successful and, depending on the nature of the problems encountered, long-term maintenance and monitoring may be required. Much of the legislation affecting the operational production stage now limits the extent of land degradation and long-term pollution, increases safety at waste disposal sites, and aids the potential for successful transfer to an alternate post-mining land use.

The initial rather narrow focus on the direct effects of environmental pollution and the immediate control measures adopted have become gradually more diffused over a wide range of environmental concerns, thus increasing the complexity of mining operations. The focus of attention has grown to interpret pollution as a measure of resource "misuse" requiring more-stringent resource management based on sound environmental principles. As the 1970's progressed, concerns over rapidly depleting resources — through actual scarcity and over-consumption — has led to increased concern for the conservation of resources. Restricted access or use of certain renewable and non-renewable resources has become a more important element in the planning process. Environmental problems related to new resource developments can no longer be dealt with in isolation from the social and political environment of our society.

The pressure of the energy crisis in 1973 focused our attention on the growing need to reconcile problems involving resource development, environmental protection, resource conservation, and ultimately the competition for lands created by them. The dilemma is a product of our early history of economic development dominated by trade in natural resources. Our prosperity still depends on the exploitation and export of natural resources, whether renewable or non-renewable, all of which are dependent on the allocation and management of land. This tradition of resource exploitation has had its price, namely a deteriorating land-resource base, a lack of conservation, and a failure to pay attention to the overall effect that exploitation of both renewable and non-renewable resources has had on the environment. The past decade has shown that our productive land-resource base and mineral resources are more limited than once supposed.

The mining industry, as a principle developer of one sector of our natural resource base, has found itself in an increasingly confusing situation since each level of government has adopted various approaches, often radically divergent, towards the resolution of resource development and environmental issues relating to land management. This has led to the continual need to adjust, from province-to-province and year-to-year, to the complicated division of decision-making powers spread among the three levels of government, often with overlapping jurisdictions. Further complications can arise even within one level of government where conflicting objectives occur between or within departments over the use and management of the same parcel of land.

Concern is growing within the industry that the increasing complexity of regulations, policies, and guidelines designed to protect and conserve our resources has led to a considerable delay, not only to the development of mines, but also to all resource developments. It raises the fundamental question in the 1980's of how to balance society's requirements for continued economic growth with its desire to preserve the environmental quality of the land resource base. This illustrates the intimate relationship that exists between the exploitation and use of mineral resources and its consequences for the environment.

..."the environment is integrated, and its components are linked by dynamic processes. We cannot use or affect any part without affecting some other parts. No matter how beneficial for our own desired purposes the principal intended results of our activities may be, our actions are bound to cause effects additional to the principal effects we have in mind. Such additional or unintended effects may not be to our advantage, and then we have the problem of controlling the environmental consequences of our own environmental control." (Roots, 1977).

The problem of meeting human needs and satisfactions has meant attempting to achieve a delicate balance in utilization between renewable and non-renewable resources. In order to accomplish this there is a need for a greater capacity than exists today to take sufficient administrative and resource management measures well in advance of new developments in order to recognize and implement trade-offs which may be required to achieve the greatest regional and/or material benefits. In the case of new mine developments, a greater understanding of the mining industry and some of the characteristics unique to it will be necessary to achieve this delicate balance. At the same time, the mining industry must adopt a greater understanding and desire to alleviate the perceptions and fears — real or otherwise — that past mining developments have engendered in the minds of the public.

PURPOSE OF THE STUDY

The purpose of the study is to analyze to what extent the public view of the industry is valid, and to examine the real nature and extent of the impact of the mining industry on the land resource.

Despite the controversies, debates, studies, and the resulting environmental regulations, very little is presently known regarding the magnitude of the impact of mining on the land-resource base. Quantification of land use and the effects on land use resulting from mining activities have been overlooked or neglected except for some local and industry-specific studies. Generally what has been documented on the mining process is that which is easiest to identify: the obvious visual disturbances of waste dumps, open pits, and tailings ponds. Meaningful national studies or inventories of land damaged or adversely influenced by all aspects of mining activity are non-existent. This neglect has made it difficult to assess objectively the relative or absolute effect of mining activities on the land. In particular, it raises a number of unanswered questions about the use of Canada's renewable and non-renewable resource base.

The specific purpose of this study is to provide an overview of the scope of mining land use activities. These include the nature and extent of land degradation processes attributable to mining, their effects on neighboring land resources, the potential for land use conflicts that may arise, and what progress has been made in the field of reclamation to reduce the effects of land disturbances.

A more general purpose of this study is to increase the understanding between the proponents of mining developments, environmental protection, and resource conservation. This will be increasingly necessary considering the difficult national choices that will have to be made in the 1980's between the goals of improved environmental quality, the reality of scarcity of important resources, and the maintenance of a viable economy so dependent on resource exploitation.

Diamond drilling; open-pit copper mine, Murdochville, Quebec
NFB — Phototheque — ONF, Jean-Paul Bernier

Chapter Two

NATURE OF MINING

MINERAL RESOURCE CHARACTERISTICS

Mineral resources whether metallic or non-metallic are defined as accumulations or concentrations of one or more useful substances that are, for the most part, sparsely distributed in the earth's outer crust (Bateman, 1952). Essential to this discussion of the nature of mining activities is a brief description of the range and general characteristics of the mineral resources found in Canada and how they influence the various stages of mining (Table 1).

METALLIC MINERALS

Metallic deposits are concentrations of formerly diffuse metals which are generally bound chemically with other elements to form "ore minerals". Ore minerals are found interspersed with non-metallic minerals or rock matter called "gangue". The "ore", commonly referred to as anything that is mined, consists of ore minerals and gangue from which one or more metals may be extracted at a profit. Monomineralic deposits (e.g. gold, gypsum, silver) which can be mined directly for these commodities are rare. Eight common elements, silica, potassium, sodium, calcium, oxygen, aluminium, iron, and magnesium comprise more than 98 percent of the earth's crust. Of these, only aluminium, iron, and magnesium have commercial value and they seldom occur in economic concentrations (Figure 1). Key metals such as copper, lead, zinc, and molybdenum comprise less than one-third of one percent of the earth's crust.

Ore minerals occur as native metals, of which gold is an example, or as combinations of the metals with sulphur, oxygen, silicon, or other elements. Several different types of ore minerals may be the source of a single metal. For example, copper can be obtained from ore minerals such as chalcopyrite, chalcocite, cuprite, and malachite; indeed one or more of these may occur in a single deposit. In addition, a single ore deposit may have several metals, for example the Lornex mine in British Columbia yields copper, molybdenum, and silver.

The non-metallic gangue materials are usually discarded in the treatment of ore. However, in technical terms some gangue may include metallic minerals, such as pyrrhotite or pyrite (two forms of iron sulphide) which is usually discarded.[1] The most common gangue minerals are oxides (quartz), carbonates, sulphates, and silicates. Some rock wastes have been utilized in the construction industry as components of asphalt and concrete, or for other industrial uses. At some time in the future, however, it may be economical to produce other items of commercial value such as bricks, fertilizers, additives, mineral fillers, and chemicals from mining wastes (Collings, 1975).

The ultimate decision to develop a mine depends on the quantity and price of the metals in the deposit and upon the cost of mining, processing, transporting, and marketing the final product. However, this in turn depends in part on the geographic locations and the quantity and grade of the ore deposit. A high-grade iron-ore mine located on an Arctic island might not be competitive because of the high cost of extraction and transportation, whereas a very large low-grade copper deposit located in an established mining region could well become operational. Other known uneconomic mineral reserves must await new advances in mining, milling, and smelting technology to transfer them into profitable mineral ores.

In many instances, the value of an ore is dependent upon associated metals that are present in small amounts. Often deposits of copper, lead, and zinc are uneconomic without minor amounts of gold and silver. In Canada, ores that commonly yield either two or three metals are those of gold, silver, copper, lead, zinc, nickel, cobalt, antimony, and manganese. In addition, silver is often associated with gold, and gold is extracted as a by-product of many other ores. Some complex polymetallic ores yield four or more metals, such as the zinc-copper-silver-lead-gold or nickel-copper-gold-silver-platinum-cobalt-selenium-tellurium-iron complexes. Many of the minor associated metals are

[1] Some mines stockpile pyrrhotite wastes separately for its potential iron content sometime in the future.

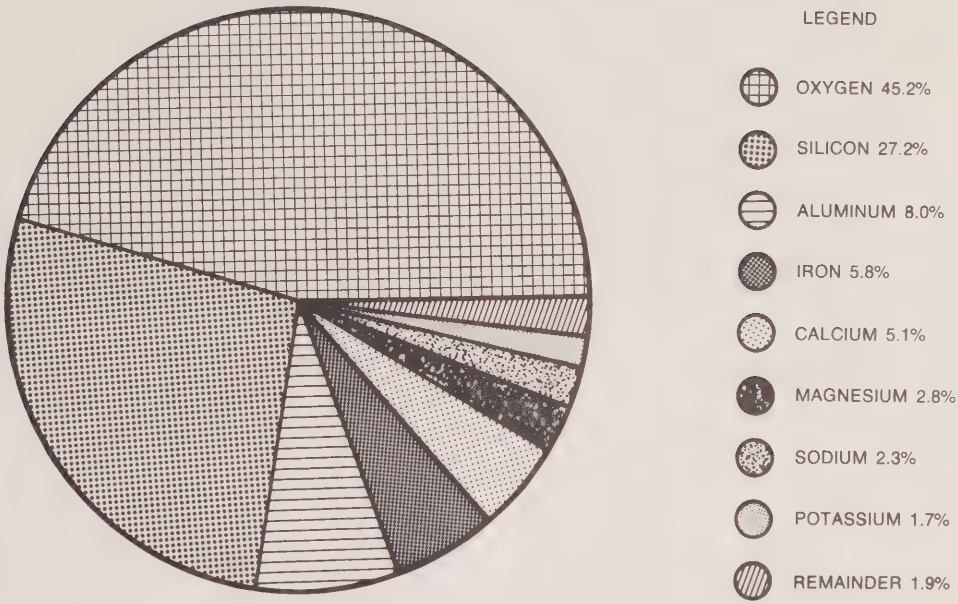
Working stope, underground gold mine
NFB — Phototheque — ONF, George Hunter

TABLE 1. MAJOR CANADIAN MINERAL SYSTEMS AND PRINCIPAL MINERAL COMMODITIES

Mineral Systems	Production for domestic needs but exports very large	Production primarily for domestic needs but some exports	By-product production
METALLIC			
Ferrous	Iron ore	Iron and steel metals Ferroalloys (including columbium, molybdenum and nickel)	Rock wool Remelt iron
Non-ferrous	Ores and metals of: Copper Molybdenum Columbium Nickel Lead Zinc Aluminium metal Gold ores	Ores and metals of: Magnesium, Cesium, Mercury (irregular) Tungsten, Niobium (Columbium) * Individual gold, silver cobalt mines, here.	Gold * Cadmium Silver * Selenium Platinum Tellurium Cobalt * Antimony Tin Bismuth
NON-METALLIC			
Industrial materials	Asbestos ores Titanium dioxide	Salt Mica Talc Barite Nepheline Quartz	Sulphur (natural gas and smelter gases)
Construction materials		Ores and products of: Aggregates (Sand, gravel and Stone) Clays Cement Lime Gypsum	
Fertilizer materials	Potash	Mixed fertilizers: Phosphorous chemicals Lime and limestone Peat moss	Nitrogen and sulphur from natural-gas processing are used. Salt produced.
ENERGY-RELATED	Uranium	Oil (Oil Sands) Coal	Sulphur Coke

Source: Dep. Energy, Mines and Resources, 1976.

FIGURE 1. CHEMICAL COMPOSITION OF THE EARTH'S CRUST



not recovered in the metal extraction or beneficiation processes but rather in the further processing through smelting and refining operations.

Thus the initial ratio of ore minerals to gangue is important, and, although the ratio varies considerably, the gangue dominates under most circumstances. The metal content of an ore is expressed as a percentage or, in the case of precious metals, in grams/tonne.

The higher the price of a metal, the lower is the metal content necessary to make it profitable. Iron ore usually requires 30 to 60 percent iron to be profitable, whereas molybdenum requires as little as 0.5 to 3 percent, and gold less than 1/1000 of one percent (0.3 ounces/ton). The lower limit is fixed by economic considerations and varies according to the nature and size of a deposit, its location, metal price, and cost of extraction. Due to the high amounts of valueless gangue in metallic ores, they are subjected to beneficiation processes at the mine site whereby the ore minerals are separated from the waste mineral, concentrated, and the waste ore discarded. Often as much as 5 to 30 tonnes of ore must be processed to yield a single tonne of concentrate containing most of the desired metal.

NON-METALLIC MINERALS

In dealing with non-metallic materials the term "ore" is not generally applied, but rather the name of the material itself is used, for example, coal, salt or asbestos. The undesired materials in non-metallic mines are referred to as "wastes" rather than a "gangue". Non-metallic materials are more common and more widely distributed; therefore, their price is generally lower than that of metals. With few exceptions — for example gemstones or asbestos — the deposits consist predominantly or entirely of the desired mineral, with little waste being generated. However, large quantities of overburden may have to be removed and stored prior to extracting the desired mineral; for example, coal in strip mines. The non-metallic minerals consist of a wide range of substances utilized in huge quantities (*see* Table 1), including industrial materials (asbestos, salt, mica and quartz); construction materials (sand, gravel,

crushed stone, clay, gypsum and limestone for cement); and fertilizers (peat and potash).

Beyond the extraction stage, further processing is usually limited to beneficiation processes of mechanical concentration, flotation, or washing (Figure 2). Smelting and refining are not required for non-metallic materials, and therefore the determination of the economic viability of a deposit is not as heavily dependent on the proportion of gangue as it is in the case in metallic ores. The market price obtained, and hence the economic viability of non-metallic deposits, is dependent not only on its physical and chemical properties, but even more importantly, on the location and distance of deposits from markets. This is particularly true of materials with high bulk and weight and low value such as sand, gravel, crushed stone, or limestone where transportation is the main factor determining the cost of competitiveness.

THE MINING PROCESS

Most mines follow a progressive sequence of events which usually fall into three broad stages — pre-production, production, and post-production — with relatively distinct phases and activities associated with each. The major phases of each stage in the mining process have been generalized (*see* Figure 2) to accommodate most mining situations.[2] The actual number of phases necessary at any given mine site is determined by the nature of the ore and the form in which the final product is desired. Because of variations in ore bodies, no two mines are the same; hence they vary in scale of production, layout, methods of extraction and ore treatment, and potential for expansion. Thus, for example, a copper ore must be extracted, milled, smelted, and refined to obtain the desired prime metallic copper, but coal and asbestos need only be extracted and milled (crushed, cleaned, and sorted).

PRE-PRODUCTION STAGE

The pre-production stage is the period during which capital expenditures are the highest. In terms of time, it generally requires five to eight years depending on type, size, and location of a deposit to bring a new mine to the production stage. However, the exploration phase is a continuing process that has no real time limit. Even after a mineral deposit has been discovered and developed, further exploratory work must be conducted. At any given time, many companies are engaged in exploration activities in Canada. In 1979, there were approximately 500 active exploration companies in Canada, excluding oil and gas (Laughlin, 1980). This is a decline from a high of 750 in 1969. The greatest decline has been in smaller companies.

This is the stage when the technical possibilities of mining are assessed, and the likely costs of extraction, beneficiation, and processing are investigated. The decision whether or not to mine and to take the necessary commitments to environmental controls, concurrent and post-mining reclamation procedures is taken at this stage. The environmental controls are an integral part of the cost of production, and, like other cost factors, can alter future production costs if changed from those originally described. This applies primarily to controls for air and water pollution. The exploration and development phases are the main components of the pre-production stage of mining.

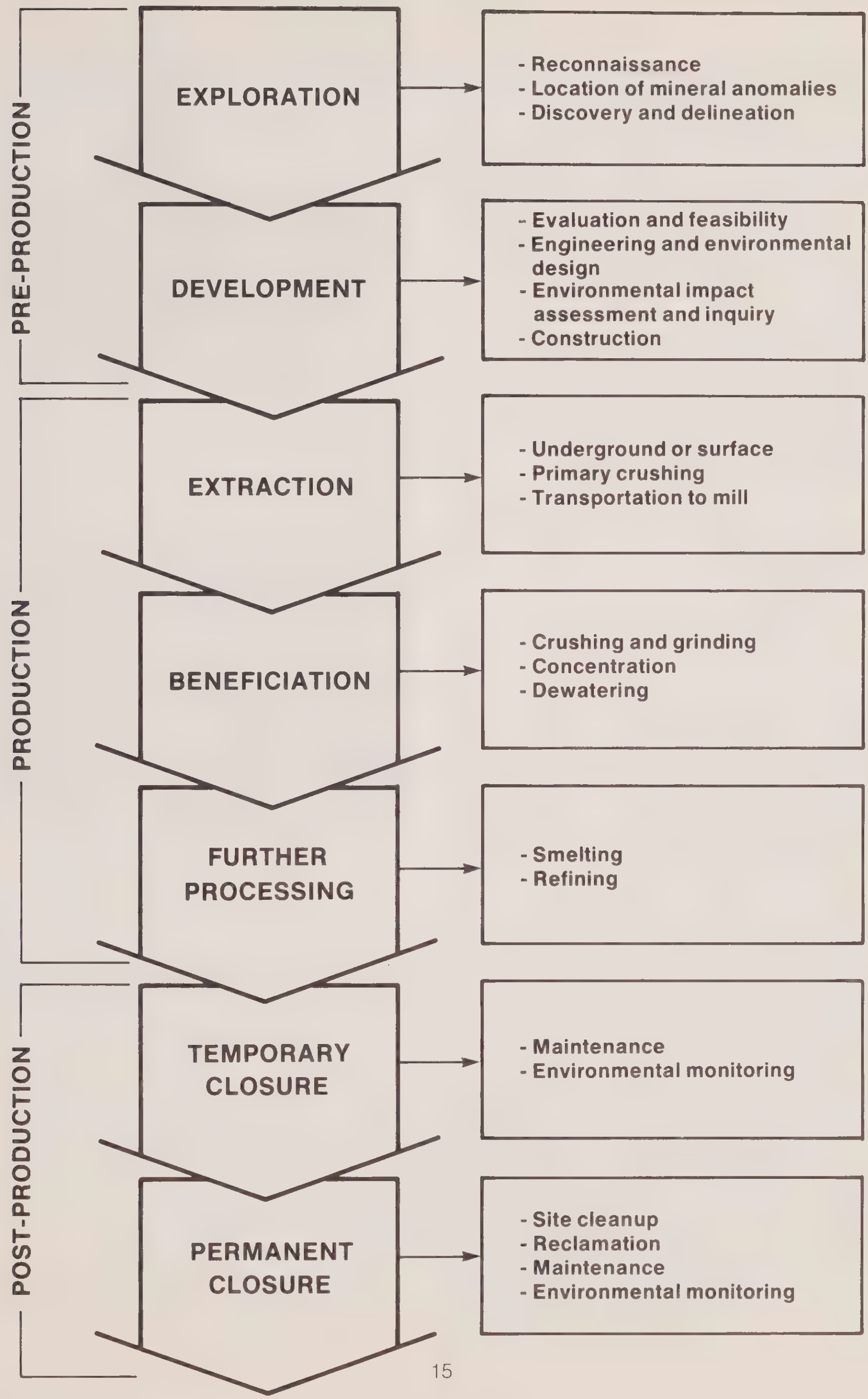
Exploration

The main objective of the exploration phase is to find geological, geophysical, or geochemical conditions which differ from that of its surroundings. The difference from the "norm" is called an "anomaly", but its presence does not guarantee that an ore body or deposit is present. Therefore anomalies are investigated further through a wide range of scientific methods that include geological, geophysical, and geochemical techniques. In the period between 1970 and 1977 the exploration techniques credited for major discoveries were as follows: geophysics, 54 percent; geological deduction, 24 percent; prospecting, 18 percent; and geochemistry, 4 percent (Laughlin, 1980).

Exploration is costly and the further that it moves into remote areas the higher costs become. In fact, the process has often been alluded to a search for "the needle in the haystack". For example, of the 10,000 known mineral showings in British Columbia less than 100 have been developed into significant mines (Gunn, 1979). At this time, a distinction should be made between the primary and continuous geological surveys and mapping programs conducted by federal and provincial agencies, and the more concentrated cost and market-conscious searches for a profitable ore deposit conducted by members of the mining industry. In practice, there is a degree of overlap, whereby the government surveys may reveal geological anomalies in the course of their mapping and the private mining

[2] A more complete list of the various activities that take place in each phase of the mining process is provided in Appendix I. Included in the appendix are operations that would normally have an effect on the land surface in the immediate vicinity of the mine site. It is evident that some operations are constantly repeated throughout the lifetime of a mine.

FIGURE 2. MAJOR STAGES IN THE MINING PROCESS



companies use the findings to aid them in the expensive process of further exploration, selective drilling, and testing.

Generally the exploration phase follows the sequence of events outlined below (Annis *et al.*, 1976):

(i) Reconnaissance: Initial search to determine regional anomalies by regional reconnaissance of a geological, geophysical, geochemical or photogeological nature. Usually initiated by airborne geophysical techniques measuring magnetic conditions and resistance to elective currents.

(ii) Location of Local Anomalies: Follow up by ground exploration techniques (a combination of geochemical and geological sampling and geophysical grid surveys) in the prospective zones defined in (i) above. Usually done for two reasons (United Kingdom, 1972):
  (a) may be simple extension of the initial survey to reveal characteristics and basic structure when existing knowledge is inadequate; or
  (b) carried out for the express purpose of proving the existence of a discrete area of mineralization.

(iii) Discovery and Delineation: By detailed geology, stripping, trenching, adits, or diamond drill testing of the local anomaly. If a drill hole proves promising (well mineralized), a more intensive drill program to define limits of the mineralized zone will be planned in order to obtain an accurate three-dimensional picture of the potential ore body.

During the exploration phase, activities such as construction of access roads, exploration trenches, adits, pits, and drill pads are the most disruptive in terms of noise and disturbance to the land surface and local drainage patterns.

In addition, the cumulative effect of thousands of kilometres of geophysical grids cut through vegetation and surface soils can cause considerable erosion, sedimentation, and wildlife disturbance. This is particularly evident in environmentally sensitive areas such as the tundra. With careful planning, however, and the increased use of specialized equipment and helicopters, much of the damage can be minimized. More significant in reducing the effects of exploration on the environment are new regulations and guidelines directed towards reducing the scale of operational activities and the imposition of reclamation requirements.

Seismic exploration, Northwest Territories
NFB — Phototheque — ONF, Ted Grant

Exploration base camp, Northwest Territories
NFB — Phototheque — ONF, Ted Grant

Development

Exploration and discovery are only the preliminaries to the long process of mine development. The discovery of a potential ore body will have to be followed by further geological analysis and detailed studies in order to establish:

(i) The size and value of the ore deposit (quality, average grade, and tonnage of ore);

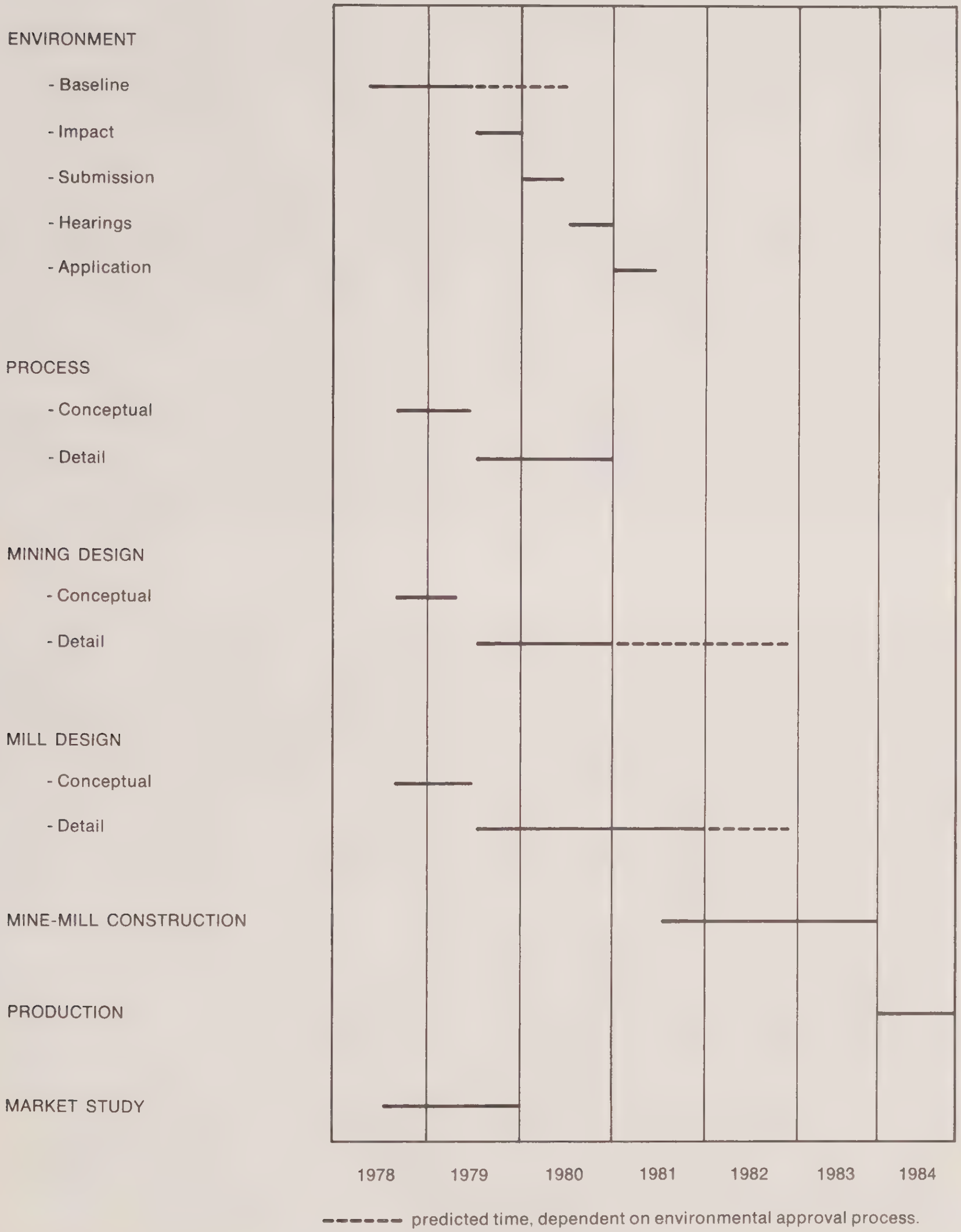
(ii) the best method of extracting and processing the ore;

(iii) the time required to prepare for production;

(iv) the ideal rate of production; and

(v) the life of the mine based on that rate of output (subject to unforeseen difficulties).

FIGURE 3. MINERAL DEVELOPMENT SCHEDULE (Esso Minerals Canada: Midwest Deposit, Saskatchewan)



Source: Fish, 1979

Although a mine may be developed initially to the stage that production can be initiated on the basis of favourable answers to the above studies, further work will occur both on the original ore deposits and other neighboring parts of the mine property. Full knowledge of the extent or potential of an ore discovery is never actually available, even when a mine is judged as capable of sustaining production on an economic basis. While these activities are being conducted a parallel set of activities must be undertaken; namely, securing financing and markets and developing transportation, accommodation and service facilities, and environmental protection measures.

An example of the time involved is illustrated by the proposed new Midwest Lake uranium mine in northern Saskatchewan (Fish, 1979). The initial uranium discovery was made in 1969, when exploration teams located a train of small uranium-bearing sandstone boulders in glacial debris; it took eight and a half years to find their source. The search involved ten different geochemical and geophysical surveys, and four diamond-drilling programs totalling 128 holes. Drilling first encountered low-grade uranium mineralization in 1977, and has continued in order to further delineate the ore body. In 1978, ore reserves were estimated at 97 million tons of U^3O^8 at 68 lb per ton, all of which are considered mineable. The ore also contains nickel, cobalt, and silver. A development schedule for the Midwest deposit proposed by Esso Minerals Canada (Figure 3) reveals projected mine and mill construction to begin in 1981 with production to start in 1984. Details of the environmental requirements and approximate time involved are also indicated, as well as the overlap with the design stage.

Generally, the development phase of mining can be broken into four broad areas of activity: evaluation and feasibility studies; engineering and environmental design; environmental impact assessment and public inquiry; and construction, between which there is considerable overlap and interdependence.

The sequence of events associated with the development of an ore body are described as follows (Annis *et al.*, 1976):

(i) The estimation of possible reserves by control drilling of discoveries and preliminary evaluation of mining and metallurgical technologies applicable.

(ii) Underground exploration and sampling to confirm preliminary reserve estimates and determination of the optimum conditions for extraction by study of models and testing with bulk samples.

(iii) Economic and market evaluation: study of necessary investments and current market conditions for the metal or minerals. Evaluation of financing required is also included.

(iv) Decision to develop the mine and start production, usually follows a positive economic and market evaluation.

(v) Construction of mine-mill complex and related facilities.

The conceptual aspects of the engineering design of the proposed mine, mill, and environmental protection facilities may evolve early in the development process, but several factors affecting the final appearance of a mine site are:

(i) limitations imposed by physical characteristics of site;
(ii) physical/chemical characteristics of the desired minerals to determine type of mine and mill; operation to be used;
(iii) problem of waste disposal;
(iv) control of particulate emissions;
(v) choice of external and internal transportation modes; and
(vi) off-site essential services (power, water, accommodation, etc.).

The physical nature of the ore and surrounding rock, and the shape and structure of the ore body determine the mining method used and the mine drainage problems that may be encountered. The mineralogy and chemistry of the ore and host rock determine the beneficiation (comminution and concentration) processes. Finally, the local environmental setting, — topography, drainage, amount and quality of water, and climate — sets the constraints on the mine layout, and influences the engineering and mechanical processes and, transport methods and equipment used.

The design of waste disposal facilities and particulate emission controls is very important in terms of the actual land requirements and potential effects that the final mine layout may have on neighbouring land uses. The disposal of solid wastes remains a major problem in the design of a mine. Rarely is there an alternate use for the vast amounts of waste material (unconsolidated overburden, waste rock, tailings, slag, slimes, etc.) generated during the course of the mining process. Not only must the selection of disposal sites for the waste be economically viable, but they must also cause the least disruption and damage to existing land uses and ecology of the area. The most difficult waste disposal problems are associated with metallic mine tailings

Exploration adit: development of lead — zinc — silver underground mine, Cadillac Explorations Ltd., Prairie Creek, Northwest Territories.
W.B. Blakeman, Environment Canada

Settling pond with plastic liner for water pumped from underground exploration activities, Amok mine, Saskatchewan
W.B. Blakeman, Environment Canada

derived from processing of ores. In many instances they require careful handling due to the presence of sulphide minerals and heavy metals and their potential to contaminate groundwater and surface drainage systems. For example, the majority of operating Canadian metallic mines have sulphide ores which tend to oxidize when exposed to air, water, and certain anaerobic bacteria. If the tailings contain insufficient buffers such as carbonates to neutralize the acidic solutions, then in the course of oxidation of the sulphide minerals — particularly pyrrhotite and pyrite — sulphuric acid solutions are generated, allowing heavy metals present such as copper, lead, zinc, and cadmium to be dissolved and leached out of the tailings. The leaching of heavy metal ions from the mineral wastes is a natural process which can make toxic elements available to various living organisms. Hence, tailings disposal facilities have to be designed to ensure that toxic or other hazardous substances produced are contained and effectively treated (neutralized) within the mine site. Measures must also be considered to control the nuisance factor of wind-blown tailings as well as possible contamination of land and water courses. If uranium tailings are involved there is the added consideration of the presence of radon gas and radioactive particles.

A key factor in ensuring the success of this containment is a constant "monitoring" program, both during the operating phase and after the cessation of mining. This practice was not always carried out in the past. In this case, the time factor is most important, since it is not the total amount of suspended solids and heavy metals discharged into the air and water leaving the mine, but rather the concentrations of these elements which eventually accumulate in the environment beyond the mine site on a local or even global scale. Since no two mines or local environments are the same, there is a need to know how mine and waste disposal activities change or alter the original environment on a local and regional scale. Therefore much data must be obtained for comparison of the operation's effect on the environment during the production and post-production stages.

In addition to the actual area occupied and influenced by mine wastes, the spatial distribution of transportation facilities plays an important role in the eventual configuration of the mine site. Although economic and operational factors most often determine the transport routes and modes chosen, consideration must be given to minimizing disturbances and the dispersal of residuals. Internally, few systems can rival truck transport for low-cost/low-mileage haulage, but the use of extensive roads for haulage of waste rock and even pipelines to transport tailings over extended distances to impoundments and settling ponds can further isolate and neutralize relatively untouched parcels of land. By exposing lands to potential contaminants from air- and water-borne residual wastes, there is increased potential for further degradation of this resource base.

The influence of the Environmental Impact Assessment and Inquiry process on the design and layout of the mine has already been discussed in the introductory chapter. But in terms of time, (*see* Figure 3) the entire process starting with environmental baseline data collection through to the final approval of the mine development will require approximately two to three years. This means the decision on the detailed mine and mill design must wait until the final approval has been obtained. Only then can the practical construction of the mine and its facilities begin.

It is during the pre-production phase of the mining process that the greatest amount of equipment movement, disturbance, dust, and noise occurs (*see* Appendix I).

PRODUCTION STAGE

During the production stage the mine usually operates as planned, subject to modifications caused by changes in grade, quantity, physical nature of the ore, technology, management, or market conditions (Roots, 1977). This stage involves the extraction, beneficiation, and further processing phases of mining, although all three may not be required to produce some mineral products. During the extraction phase, sorting, ore removal, primary crushing, and the removal and disposal of overburden and waste rock take place at the mine site. During the beneficiation phase, the ore is subjected to further reduction in size and is concentrated at a mill where a large fraction of the gangue is removed from the ore, and constitutes the tailings. The mill is usually located near the mine site, largely due to limitations imposed by the cost of transporting large quantities of material of low unit value. The desired minerals in complex ores are separated from each other in the mill prior to smelting. Further processing of minerals/metals (smelting and refining) may be carried out at any distance from the mine site to produce the final desired element or compound. Many high-grade monometallic ores can be shipped directly to a smelter, but this practice is not economical for low-grade or medium-grade monometallic ores. Multimetallic ores must be milled (concentrated) even if high grade, in order to separate the desired minerals.

Coal Strip mining, using a dragline, Saskatchewan
W.B. Blakeman, Environment Canada

Cypress-Anvil's open-pit mine. Faro, Yukon Territory
NFB — Phototheque — ONF, George Hunter

It is during the production stage that environmental problems emerge. Although most effects of land disturbance are immediately visible, those brought about by changes in the quality of air and water can be more subtle, far-reaching, and complex. Hence, regulations for environmental protection have been introduced by Provincial and Federal governments which concentrate on controlling pollution caused by gaseous and particulate airborne emissions and liquid effluents during the life of a mine.

Extraction

The mining techniques employed to extract minerals divide into two broad categories, i.e. surface and underground, and those used at any particular site are determined by the geological and topographical conditions. Three broad types of mineral deposits are found: massive or veined deposits highly variable in size, shape, and inclination which are common sources of metallic minerals; bedded, uniformly thick sedimentary

TABLE 2. TYPE AND NUMBER OF OPERATING MINES IN CANADA

PROVINCE/ TERRITORY	COAL		METAL				INDUSTRIAL MINERAL				LIME
	U	S	U	U/O	O[a]	P	U	U/O	O[b]	S[c]	O
Newfoundland			2	1	2		1		6		
Nova Scotia	6						2		9	1	
New Brunswick		1	4		1				3		1
Quebec			28		9		2	2	23		3
Ontario			44	1	14		5		16	2	7
Manitoba			12		2				6		1
Saskatchewan		5	2		1		9		8	2	
Alberta	4	9							7	1	2
British Columbia	1	3	13		13	1			7	1	1
Yukon	1		3		1	51			2		
Northwest Territories			7	1	1						
CANADA Total	12	18	115	3	44	52	19	2	87	7	15

U - Underground
O - Open Pit
U/O - Underground and Open Pit
P - Placer (sluicing)
S - Surface

a - Of the metal open pit mines, 13 produce iron, and 20 produce a combination of copper, zinc, nickel, and lead.

b - 13 of the Industrial Mineral open pit mines produce asbestos.

c - 5 of the Industrial Mineral surface mines produce salt.

Source: Dep. Energy, Mines and Resources, 1977 and 1979a.

deposits generally more horizontal or gently inclined than vertical (e.g. coal, potash); and finally, loose unconsolidated fluvial or glaciofluvial sands and gravels (e.g. mineral aggregates, placer gold, tin).

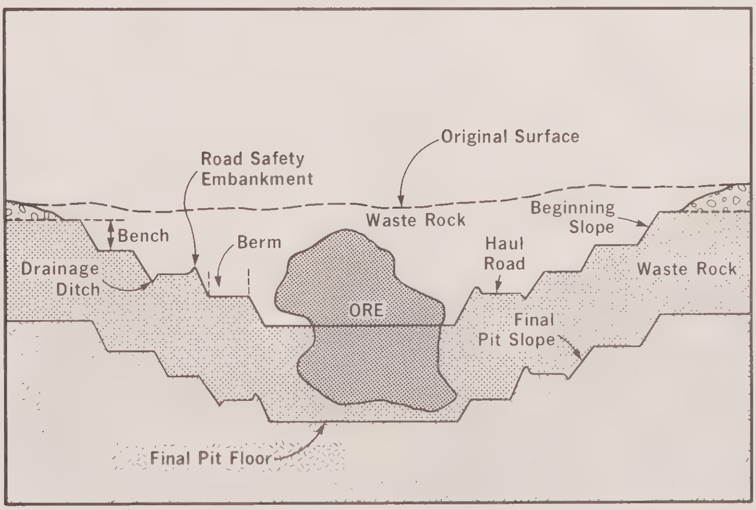
In terms of relative importance of the methods, some 66 percent of all tonnage mined in Canada in 1970, exclusive of industrial minerals, were by surface methods compared to 15 percent in 1950 (Dubnie, 1972). By 1974, the figure for metallic mines alone had risen to 79 percent and to 86 percent for coal mines (Welwood, 1976). The total for industrial minerals was 59 percent exclusive of sand, gravel, and crushed stone which are almost entirely surface operations. The most recent operators lists for metallic, industrial mineral, and coal mines reveal that 60 percent of the coal, 40 percent of the metallic (excluding placer mines), and 84 percent of the industrial mineral operations were surface mines (Dep. Energy, Mines and Resources, 1977). A complete breakdown by province and territory is illustrated in Table 2.

The actual decision to extract a mineral deposit by surface or underground mining methods is largely dictated by its depth and three-dimensional configuration. The choice of surface mining provides a number of distinct advantages, namely: lower costs-per-unit of production; more complete recovery of deposits which cannot be mined by underground methods; and finally, safer working conditions. In most cases, the ultimate factor that determines whether or not a deposit can be mined by surface methods is the depth of overburden and waste rock that overlies the deposit. The economics of overburden removal and handling effectively limit strip or open-pit techniques. This is illustrated in Figure 4, which shows that, as the depth to ore increases, the amount of overburden and waste rock to be removed increases dramatically due to the necessity to expand the working area to gain access to the ore and to maintain safe slope angles.

In some cases, surface methods are used initially, and then underground methods are initiated when the cost of waste rock removal becomes prohibitive or it is no longer technically possible. An example of this is the Creighton mine in the Sudbury district of Ontario which has operated almost continuously from 1900. It started operations as an open pit, but at the third-bench level, 200 feet below ground level the decision was made (in 1905) to terminate pit operations in favour of underground mining.

"Several factors guided the decision. . .. In winter, ice and snow hampered and frequently stopped work. Furthermore, if the pit were carried deeper than the third level, safety would require flattening the slope on the hanging wall side, which would necessitate mining only slightly mineralized

FIGURE 4. CROSS SECTION THROUGH A TYPICAL OPEN PIT MINE



material. The clinching point was that by 1905, the pit workings indicated that the ore would continue in depth for at least several hundred feet, so that mining would have to go underground sooner or later." (Boldt, 1967).

In fact mining has continued to this day with a ninth underground shaft completed in 1967 reaching 2100 metres below ground level. During this time, the methods used underground have included shrinkage, room and pillar, cut and fill, and square-set stopes.

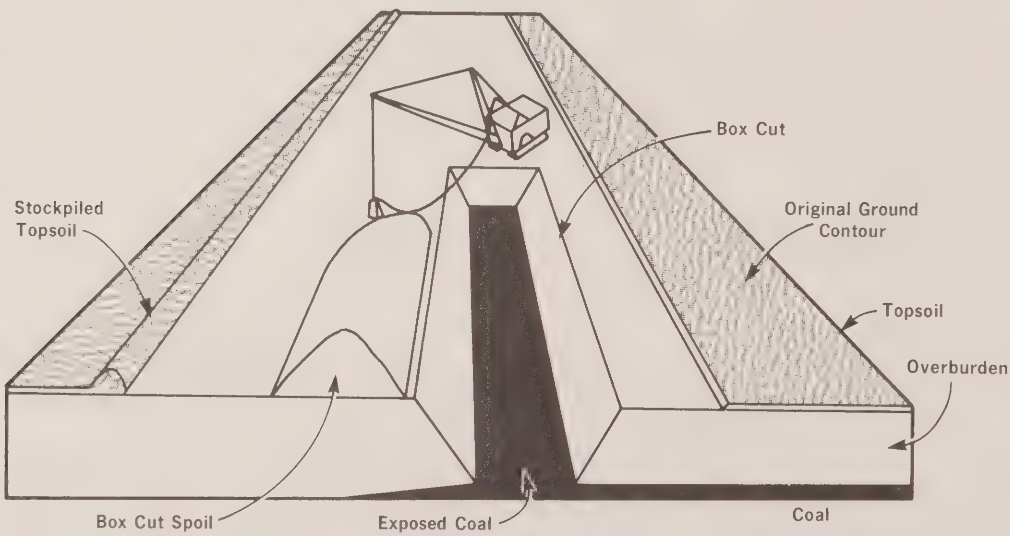
Surface Mining

Surface mining dominates the extraction of ore from relatively shallow depths. The two most important methods used to extract near-surface deposits in Canada are open-pit and strip techniques. Where massive and/or irregularly shaped ore bodies are to be recovered, open-pit methods predominate, whereas strip mining is associated with the exploitation of stratified or bedded deposits. Other methods include hydraulic and pit mining, quarrying, and dredging.

(i) ***Strip Mining:*** Also called area mining, it is used to extract near-surface bedded, deposits in flat-lying or gently sloping terrain. In Canada, this method is used almost exclusively to extract relatively shallow coal deposits. Two different methods are used to strip the soil/overburden and coal deposits, namely electric draglines, or truck shovel operations (Bielenstein *et al.*, 1979).

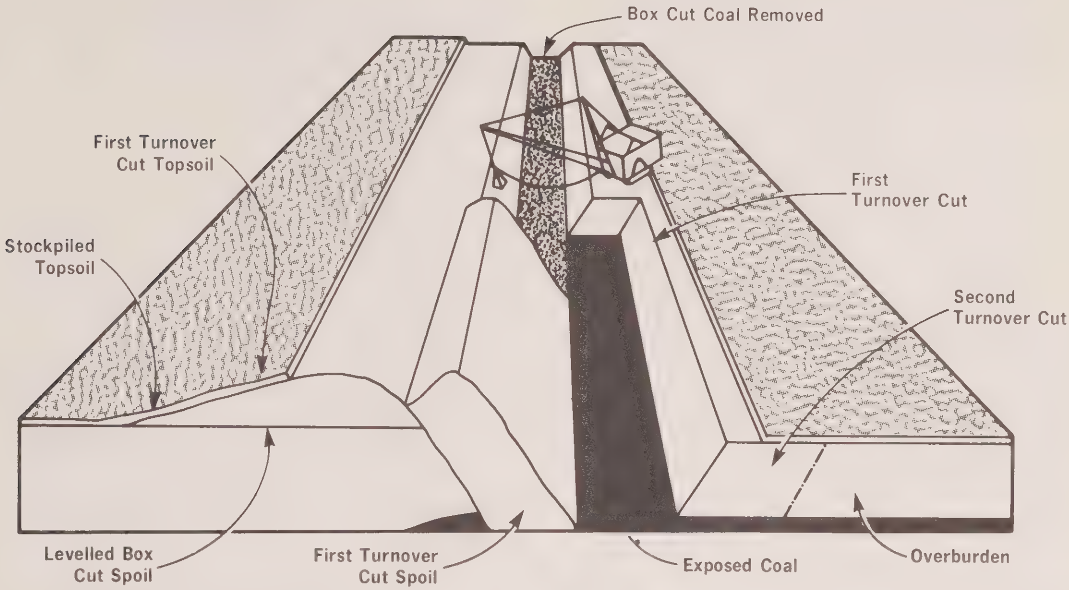
Strip mining commences at the coal seam's lowest elevation and the cuts advance up the dip or slope of the coal in order that the water may drain away from the working areas (Figure 5). At the end of the first box cut the dragline is walked to the lower end of the coal seam to start the second parallel cut (Figure 6). The coal is usually removed by truck and shovel. The overburden is cast into the trench created by the preceding cut. As mining advances, a series of parallel cuts progress across the mine property (Environment Canada, 1979*b*; Bielenstein *et al.*, 1979).

FIGURE 5. NORMAL COAL STRIPPING PROCEDURE: BOX CUT



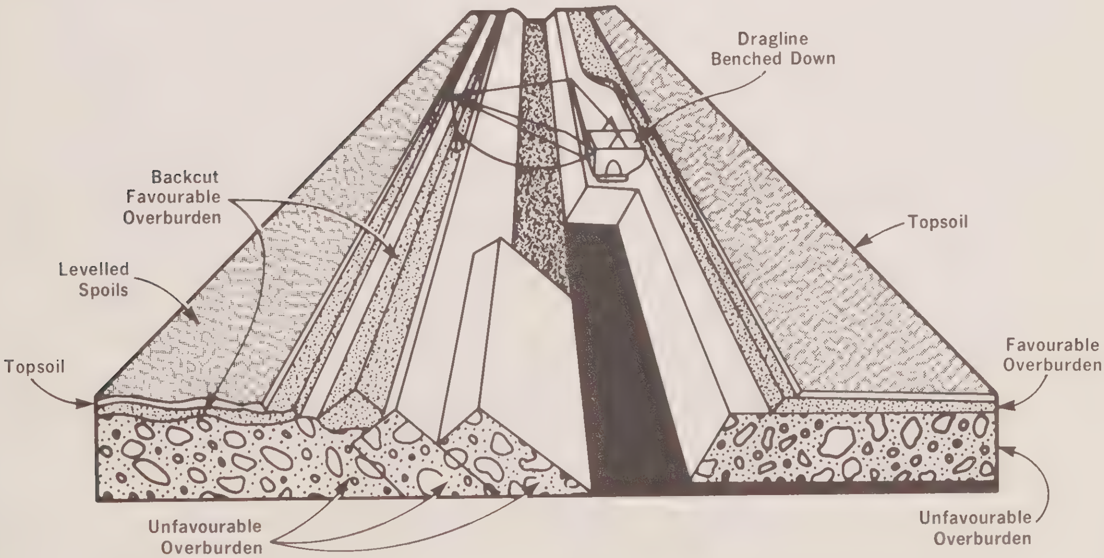
Source: International Joint Commission, 1979

FIGURE 6. NORMAL COAL STRIPPING PROCEDURE: FIRST TURNOVER CUT



Source: International Joint Commission, 1979

FIGURE 7. SELECTIVE STRIPPING PROCEDURE



Source: International Joint Commission, 1979

Unless the materials are handled selectively by the operator, the waste materials are deposited in the cuts in a stratigraphically inverse manner such that the topsoil is at the bottom followed by overburden and waste rock (Blakeman, 1980). However, most mine regulations require some form of selective material handling, placement, and storage (Figure 7). The stripped coal seams usually leave a ridge and furrow surface due to the swell factor, wherein broken rock occupies up to 1.5 times the volume of undisturbed bedrock. The stripping process is amenable to sequential land reclamation.

(ii) ***Open-Pit Mining:*** This technique is generally used to extract massive or veined minerals or coal in rough terrain from near-surface deposits. Open pit operators extract the ore from the pit and do not normally backfill overburden, waste rock, or tailings wastes to refill the pit. Generally in an open-pit procedure, top soil is collected with scrapers or bulldozers and is stockpiled for future reclamation work. Blast holes are drilled in the waste rock overburden, then loaded and fired to reduce the overburden to sizes which can be removed with bulldozers, front-end loaders, or shovels and hauled away in trucks to preselected dumpsites. Once the overburden waste is removed, drilling rigs are used to drill holes into the mineral deposits. These holes are then loaded with explosives which are subsequently fired to break up the ore. In most cases, power shovels and trucks are used to load and transport the ore.

The pit is cut downward in "benches" or steps, and slopes inward until at a certain depth it becomes uneconomical to go any deeper. The upper benches are excavated beyond the ore limits into the waste rock of the side walls (*see* Figure 4). The excavation must be considerably larger than the ore deposit so as to ensure stability of the pit slopes. In this method material-handling costs are higher than in strip mining. Although, the open-pit method offers the advantage of a high degree of mechanization and ore recovery, it has a number of constraints, namely: large volumes of waste; considerable variation in the physical and chemical characteristics of wastes from the same pit; and a deeply excavated pit is left behind on abandonment. In some open-pit mines, however, haulback techniques are used. The initial overburden and waste rock is stored or spread on an adjacent land site. Then, as the pit expands, the overburden and waste rock is trucked to mined-out areas in the pit and deposited. This haulback technique is not often used due to the extremely large quantities of waste rock and overburden involved. Most open-pit operations extract three to four tonnes of waste for every tonne of ore extracted.

(iii) ***Quarrying:*** Quarries are used primarily to extract stone for ornamental and building purposes or crushed stone for construction materials. Extraction procedures are similar to open-pit mining, but the pits are not as deep and rarely exceed 50 metres. Most quarry operations have a long life span and are located close to human settlements. Integral parts of nearly every quarry are the processing plant, settling ponds, and stockpile areas. Frequently, these activities are moved into the unused portion of pit in latter stages of extraction. Unlike other forms of mining there is very little waste rock to be disposed of, but steep high walls of rock, considerable depths, and poor drainage limit post-mining uses to general recreational purposes (Ramani and Grim, 1978; Blauch, 1978).

(iv) ***Pit Mining:*** Extraction by pit mining is the method most commonly used for sand and gravel, and is the most prolific type of mine due to the large demand for sand and gravel in construction and the relatively small size of most deposits. Normally top soil is scraped and stockpiled, often as protective berm, and equipment is limited to scrapers, bulldozers, front-end loaders, and trucks in addition to a processing plant. The ultimate design and configuration of the pit depends on the type and shape of the deposit. Most are shallow (30 metres), and irregularly shaped. They are similar in some respects to quarries, in that they require stockpiles, a settling pond, and plant area (Blauch, 1978). Related to, but not usually considered a mining operation are "borrow" pits particularly those associated with highway developments. They are usually smaller, more numerous, and side-hill excavations.

(v) ***Dredging:*** This involves the continuous removal and processing of unconsolidated mineral deposits. The dredge consists of a

floating platform which utilizes a continuous suction apparatus or mechanical digging equipment such as bucket wheels or draglines to extract the unconsolidated deposits, and processing equipment which segregates and removes the valuable mineral fraction (Ramani and Grim, 1978). It is most commonly used in placer-gold mining (some aggregate extraction) leaving waste piles similar to the ridge-and-furrow terrain of coal strip mines in the plain of southeastern Saskatchewan. The extraction process creates considerable upheaval in streams or river beds by contributing large amounts of suspended sedi-

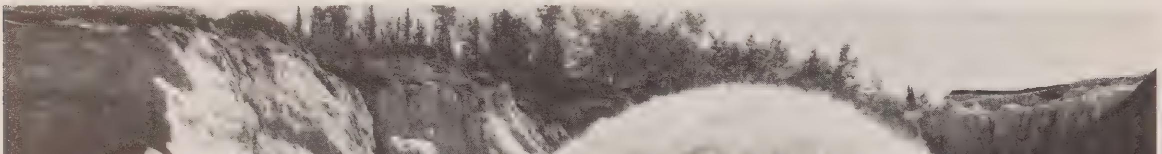
TABLE 3. AVERAGE SIZE OF LAND DISTURBANCES AT MINE SITES IN CANADA

	AVERAGE SIZE MINE DISTURBANCE	AVERAGE SIZE OPERATING MINE PROPERTY	AVERAGE SIZE CLOSED MINE	LARGEST SIZE OF MINE DISTURBANCE
METAL	(hectares)	(hectares)	(hectares)	(hectares)
All Mines[1]	77	148	30	1,219
Gold/Silver Only	44	93	29	482
All Mines[2]		124		
Underground		70		368
Open Pit		180		1,688
IRON				
All Mines[1]	195	252	58	935
All Mines[2]	327			
Underground	152			152
Open Pit	342			1,451
COAL				
All Mines[1]	335	95-614	20-60	1,430
INDUSTRIAL MINERALS				
Asbestos[1]	205			582
Potash	180			350
Sand and gravel[3]	7			
Stone Quarries[3]	17			464

* Disturbances indicated in this table refer to open pit, ship mine, shaftsite tailings, waste rock, overburden dumps and ponds. They do not include any other land area affected by facilities or operations. A more precise breakdown of these figures can be found in Appendix II.

Sources: (2) Environment Canada, 1972; (1) Murray, 1977b; (3) and Environment Canada, 1977.

Drill rigs preparing blast holes in open-pit coal seam, B.C. Coal Ltd., Sparwood, British Columbia
I.B. Marshall, Environment Canada



Hydraulic gold mining, Dawson City, Yukon Territory
NFB — Phototheque — ONF, Brian King

TABLE 4. TYPICAL SURFACE MINES: ORE AND WASTE ROCK HAULAGE

Company	Mine and Location	Products	Open Pit Size		Ore Hauled (Tons/day)	Waste Rock/Overburden	
			At Surface (ft)	Depth (ft)		(Tons/day)	%
Asbestos Corp.	British-Canadian Black Lake, Que.	Asbestos	5,000 X 2,500	350 (south) 800 (north)	14,200	36,800	72.1
Brenda Mines Ltd.	Peachland, B.C.	Cu, Mo	3,000 X 3,000	450	30,000	20,000	40.0
Cassiar Asbestos Corp.	Cassiar, B.C.	Asbestos	3,000 X 4,000	1,000	5,000	35-40,000	70-80
Eldorado Nuclear Ltd.	Eagle, Eldorado, Sask.	U_3O_8	200 X 100	80	120	300	62.5
Gaspé Mines Ltd.	Copper Mountain Murdochville, Que.	Cu	2,500 X 2,600	500	30,000	50,000	62.5
Griffith Mine	Red Lake, Ont.	Fe	6,100 X 1,800	275	14,900	19,200	56.3
Manitoba and Saskatchewan Coal Co.	Boundary Dam. Estevan, Sask.	Coal	8,000 X 100	40-80	5,500	30,000 Cu-Yd Stripped	
McIntyre Mines Ltd.	No. 9, Grande Cache, Alberta	Coal	4,800 X 2,000	820	4,000	66,000	94.2
Newmont Mines Ltd.	Bell Copper Division Gransisle, B.C.	Cu, Au	2,000 X 2,500	440	15,000	10,000	40.0
Placer Development	Gibralter Mine, Polyanna Pit McLeese Lake, B.C.	Cu, Mo	2,000 X 1,800	370	40,000	75,000	65.2
Sherrit Gordon Mines Ltd.	Ruttan, Leaf Rapids, Manitoba	Cu, Zn	2,800 X 1,640	560	10,000	15,000	60.0

Source: Canadian Mining Journal, 1980.

ments to the streams and leaving gravelly waste piles which are difficult to reclaim.

Both open-pit and strip mining involve the removal of large quantities of overburden and waste rock resulting in the disturbance of substantial areas of land. The range in size of land disturbances from recent inventories is indicated in Table 3 and Appendix II. The largest extraction sites are associated with iron ore, copper, asbestos, and coal mines. The variation in the size of these operations is provided in Table 4. In most cases, the open-pit metallic mines are several thousand feet in diameter and between 350 to 600 feet deep. The table reveals that the amount of waste rock and overburden generated from open pits as a percentage of the total material recovered from the pit varies between 40 to 72 percent.

TABLE 5. OPEN-PIT LAND REQUIREMENTS

	Afton Mines Ltd. British Columbia	Quebec Cartier Mining Co. Ltd. Mt. Wright, Quebec
Product	Copper, gold, silver	Iron
Metal content	Copper (1.01%) Gold (0.72%) Silver (5.0%)	30-40%
Estimated Reserves	34 mil. tonnes 10 mil. tonnes at depth	900 mil. tonnes
Production Rate	7,000 tonnes/day	130-150,000 tonnes/day
Estimated Life Span	15-20 years	20 years
Ultimate Open Pit	56 ha	464 ha
Tailings Dam and Ponds	191 ha	218 ha
Waste Rock Dump	149 ha	480 ha

Source: Abbott, 1975; Anderson and Robertson, 1977.

In the recent Canadian Mining Journal's annual review of mining technology (1981), the average volume of waste for the 18 mines reporting was 60 percent of the total material extracted at open-pit mines. In the case of open-pit coal mines extracting bituminous coal from steeply dipping seams in mountainous terrain (45 percent of current Canadian coal production), the waste-to-coal ratios can range up to ten- or twelve-to-one. In the same survey, of 49 underground mines responding, a third reported no waste rock lifted to the surface, whereas the remainder reported that only six percent of all the material extracted was waste rock. In general, open-pit mines produce about fifty times more solid waste than underground mines (Ripley *et al.*, 1978).

In Table 5, data from two different metal mines opened in the latter half of the 1970's illustrate the type of land requirements that can be expected over the life of an open-pit mine. The relatively comparable size of the tailings impoundments reflect the very low grade of copper ore compared to the higher-grade iron ore.

The largest open-pit copper mine in terms of mill capacity (43,000 tonnes/day) is the Lornex mine in Highland Valley, British Columbia which opened in 1972. By 1976, the estimated area occupied by waste rock was 369 hectares of land (Murray, 1977*a* and *b*).

In terms of a single surface-mining operation, coal strip mines and tar sands operations affect the largest areas of land in the extraction phase. For example, the new Saskatchewan Power Corporation coal mine near Cornach is anticipated to operate approximately 35 years producing 1.8 million tonnes of coal a year beginning in 1979 (International Joint Commission, 1979). Using a dragline with a 110 metre boom and a 69 cubic metre bucket, it strips 12 to 45 metres of overburden in 36 metre widths at a rate of approximately 100 hectares per year, including both open box cuts and parallel spoil piles. It is estimated that 41.8 square kilometres (4,180 hectares) will be directly disturbed by the mining operation during its lifetime. Similarly, the expansion of the Highvale mine south of Lake Wabamun, Alberta (to serve a new thermal electric plant at Keephills) will require an additional 3,642 hectares, extending the total area disturbed to 8,094 hectares by the end of the mine's life (Bridges, 1978).

In addition to the land disturbance caused by the surface mining of metal and coal, the extraction of unconsolidated or alluvial materials such as sand and gravel is a major contributor to land disturbance. Despite the relatively small size of the pits and the generally low volume of waste generated, the visual and environmental impacts are far more noticeable due to their vast numbers (Appendix III).

Underground Mining

Underground mining operations are as variable as the types of ore and their geological and environmental settings. While the mining methods chosen for each deposit are specific, details will be omitted here, and only the broad characteristics discussed. A typical underground mine is characterized by a series of vertical or inclined shafts, ranging from less than one metre to in excess of 7.5 metres in diameter, through which entry is made into the ground (Figure 8). The shafts are usually equipped at the top with a hoist which is used to lower and raise a cage for men and material and a skip for ore. Often a separate shaft is used for ventilation. Once the shaft(s) has been sunk it is developed for production by driving a series of horizontal "drifts" or tunnels at intervals of 30 to 60 metres vertically, in and adjacent to the ore body. Crosscuts are then driven perpendicular to the drifts to cross the ore body. Vertical workings between the drifts consist of "raises" (upward) or "winzes" (downward). The "stope" is where the ore is actually excavated. Several stopes are required because productivity from a single face would be too limited. Extraction is selective in order to eliminate as much waste as possible.

The ore is mined by drilling a series of holes into the wall or "face", loading them with explosives, and blasting the ore free. The loose ore is then loaded onto ore trucks or mine cars by gravity or mechanically and is transferred to a central collection point or loading pocket, where primary crushing may take place. Finally, the ore is raised to the surface in a skip through the main shaft.

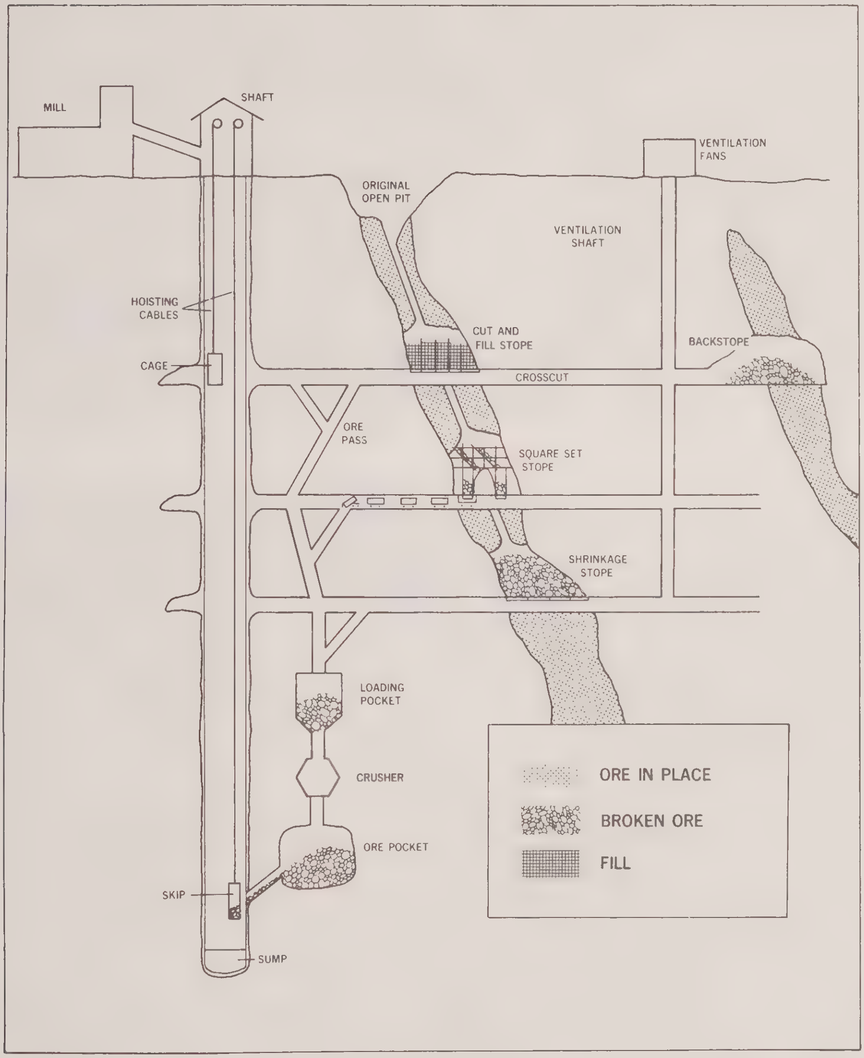
In underground mining there are many methods of extracting the ore from stopes, as well as variations and combinations of the different methods. Among the most common stoping methods used are shrinkage, cut and fill, square set, room and pillar, and longwalling. Two other less extensively used methods are hydraulic and solution mining.

(i) ***Cut and Fill:*** In this method the ore is broken in the stope, removed, and replaced with backfill. This allows for more-selective mining of the best-grade ore (that is handling as little barren rock or low-grade ore as possible) and less waste to dispose of. It has the advantages of economy and safety (Northern Miner, 1968). In some mines, a hydraulic backfill of coarse mine tailings (in the size range of sand)

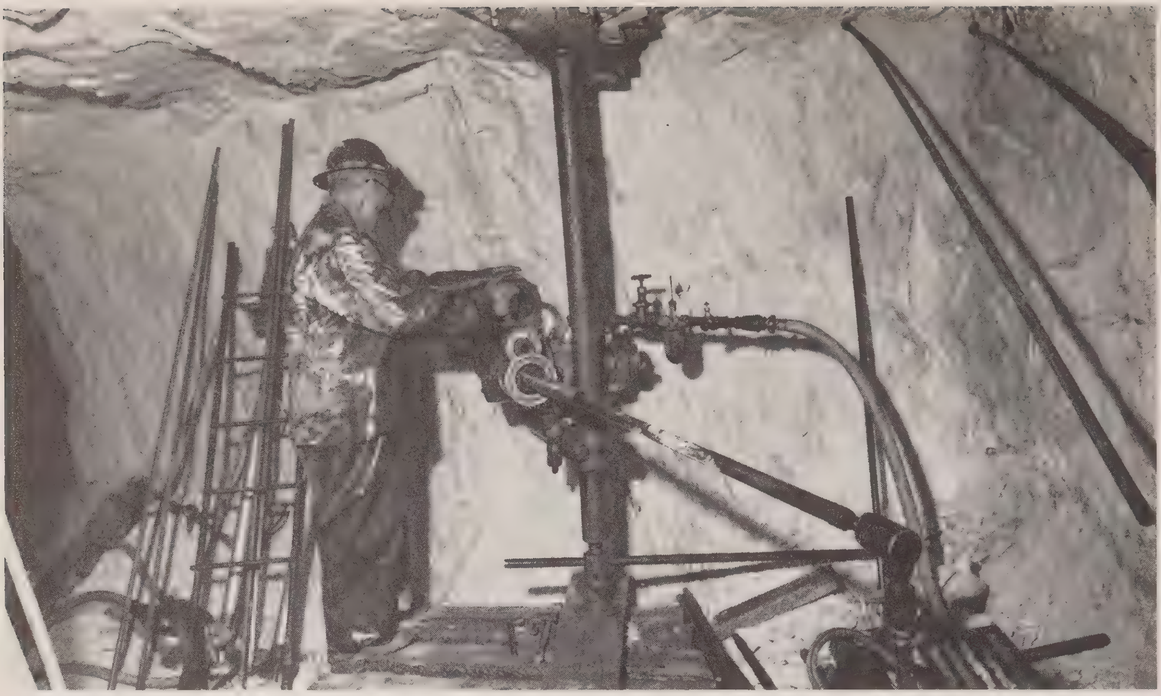

Underground mine crosscut
NFB — Phototheque — ONF, C. McNeill


Underground longwall coal operation
NFB — Phototheque — ONF

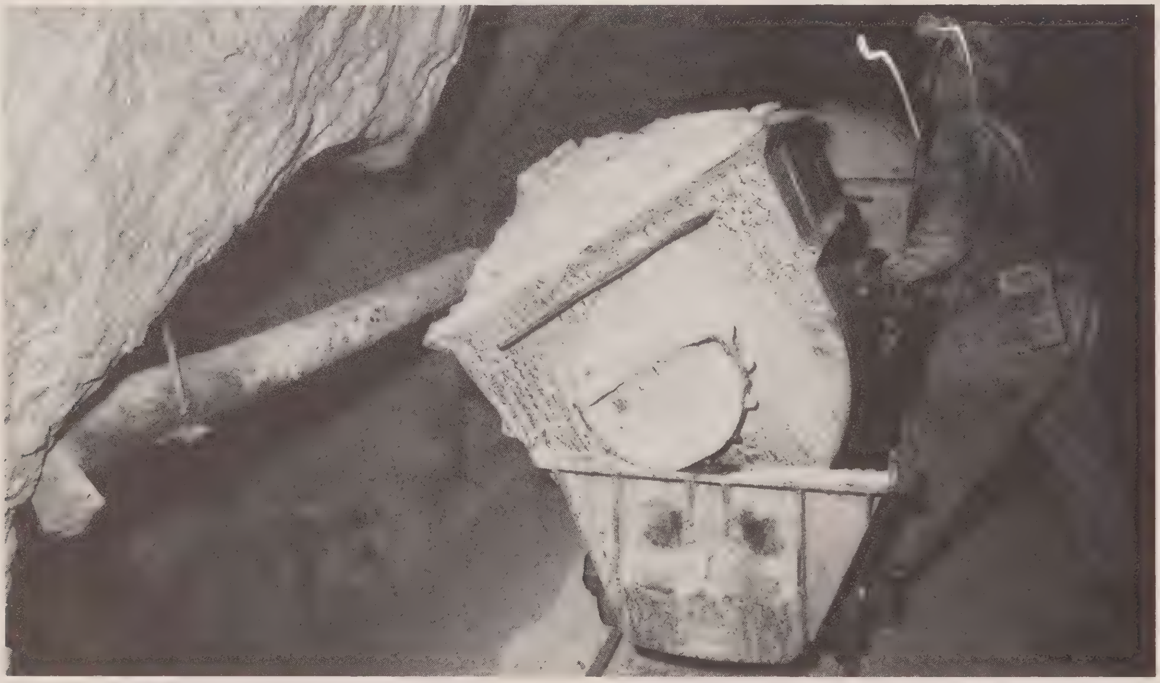
FIGURE 8. ILLUSTRATION OF AN UNDERGROUND MINE



Source: Northern Miner, 1968



Working stope, underground talc mine
NFB — Phototheque — ONF, George Karam



Talc being dumped into an ore pass
NFB — Phototheque — ONF, George Karam

is sent underground in a slurry form (Marshall *et al.*, 1974). The coarse particles settle, then water is decanted and pumped back to the surface. In some cases, cement is added to the sand/water slurry before it is pumped underground.

(ii) ***Shrinkage:*** No backfill is used in this method. Part of the broken ore is used as a working platform and support for the walls. Therefore, when all the ore is extracted, there will be a hole extending from one level through to the next (sometimes it may be filled with waste later). In breaking, the volume of ore increases by up to one-third, expanding to fill the hole (Northern Miner, 1968). This is one of the cheapest methods of underground mining. In some shrinkage stopes, if the rock walls are are not strong enough a central pillar is left separated by chutes.

(iii) ***Square Set:*** This method is used to mine ore when the ground is unstable due to its unconsolidated nature, or when the unsupported walls will not stand up readily. It consists of erecting square or rectangular sets of timbers from wall to wall and reaching upward as the ore is excavated; these support the walls and roof. The broken ore falls down slides to the chute raises (Bateman, 1952). Sometimes, the hollow squares are filled as soon as possible with waste rock to keep the roof supported as much as possible in order to provide a safe work place (Northern Miner, 1968). Economically, one drawback of the method is its high cost of operation.

The above three methods are generally used for steeply dipping ore veins, or large irregular bodies with a variety of spatial orientations or dimensions. In most cases, the mining advances.

(iv) ***Room-and-Pillar:*** This method, used widely to extract coal in Canada involves the removal of regularly spaced, square or rectangular rooms (blocks) in two directions at right angles to one another, while leaving a series of natural "pillars" to support the roof of the workings (Environment Canada, 1979*b*). It has the disadvantage of leaving behind between 20 to 50 percent of the mineral reserve.

(v) ***Longwall:*** The longwall technique is highly mechanized and makes use of three basic elements: a shearer, roof supports, and a face conveyor. The room-and-pillar and longwalling techniques may be used in advancing and retreating mining operations. These methods are particularly suited to relatively flat-lying, two-dimensional mineral deposits, which generate very little waste rock unless the seams are very thin.

"In an advancing long wall operation, two parallel access tunnels several hundred feet apart are driven from a main shaft area into a flat lying or gently dipping coal seam. The self propelled shearer with rotating cutting drums moves laterally across the face of the seam between the tunnels. As the shearer traverses the face, it cuts the coal lying between the "floor" and the "roof" and discharges it onto the face conveyor which carries it to the end of the face for discharge onto another conveyor belt or mine cars in one of the access tunnels for movement to the surface. Within the narrow working area, the roof is supported by a series of closely spaced hydraulic jacks (roof supports). Upon reaching one end of the face, the shearer works its way to the opposite end. With each lateral traverse, the shearer advances approximately .75 metres into the seam, and as the working face advances, the roof supports are moved forward, allowing the unsupported roof behind the working area to collapse. As mining progresses, the access tunnels on each end of the working face are driven forward." (Blakeman, 1980).

A retreating operation requires that parallel access tunnels be developed first to the outer limits of the area to be mined and the working face retreats from the outer limit to the main shaft area. The retreating system is more economical in the long run, than the advancing technique. However, both longwall methods allow for up to 100 percent of the ore in the longwall face to be extracted with a high degree of productivity, due to high mechanization. However barriers 10 to 30 metres in width are often left between adjoining longwall working faces, thus total recovery is in the 70 to 80 percent range.

(vi) ***Hydraulic:*** Hydraulic mining utilizes water under high pressure to cut, break, load, and transport coal from the working face to the mine mouth. In Canada, this technique is used at a single coal mine in the rocky mountains of British Columbia, where the coal seams are thick and steeply dipping. Conventional room-

and-pillar operations allow little more than a 10- to 15-percent recovery rate (up to 50 percent if rooms and pillars are equidimensional). The hydraulic method allows an extraction rate of up to 70 percent in a block, and 55 percent overall (British Columbia, 1976).

(vii) ***Solution:*** Solution mining in Canada is only used to extract salt and potash (MacWilliams and Reynolds, 1973). The solution process used to extract potash in Saskatchewan (Kalium mine, northwest of Regina) involves pumping hot water into the potash layers where it dissolves the potassium salt. The saturated solution is pumped to the surface and potassium salt extracted from the solution through evaporation and crystallization (Sas-

TABLE 6. EXAMPLES OF ORE AND WASTE ROCK HOISTED FROM UNDERGROUND MINES IN CANADA

Company	Mine and Location	Products	Ore Hoisted (Tons/day)	Waste Rock	
				(Tons/day)	(%)
Asarco Inc.	Buchans, Nfld.	Zn, Pb, Cu, Au, Ag	750	50	6.25
Cominco Ltd.	Sullivan, Kimberley, B.C.	Zn, Pb, Ag, Fe, Cd, Bi, Sb, In, Sn, S	9,600	160	1.6
Eldorado Nuclear Ltd.	Fay & Verna, Eldorado, Sask.	U_3O_8	1,400	500	26.3
Falconbridge Nickel Mines	Strathcona, Onaping, Ont.	Ni, Cu	7,500	400	5.0
Inco Metals Co.	Copper Cliff South Copper Cliff, Ont.	Cu, Ni	3,300	500	13.1
Noranda Mines	Mattagami Lake, Mattagami, Quebec	Zn, Cu, Au, Ag	2,800	150	5.1
Patino Mines (Quebec) Ltd.	Copper Rand, Chibougamau, Quebec	Cu, Au, Ag	1,900	130	6.4
Rio Algom Ltd.	Quirke II, Elliot Lake, Ont.	U_3O_8	10,000	400	3.8
Sigma Mines (Quebec) Ltd.	Val D'Or, Quebec	Au, Ag	1,644	66	3.8
Teck Corp.	Lamarque, Val D'Or, Quebec	Au, Ag	1,850	nil	---
Texas Gulf Canada Ltd.	Kidd Creek No. 1 and 2 Timmins, Ontario	Ag, Cu, Zn, Pb, Sn	14,000	1,000	6.6
Whitehorse Copper Mines Ltd.	Little Chief, Whitehorse, Yukon	Cu, Au, Ag	2,400	152	5.9

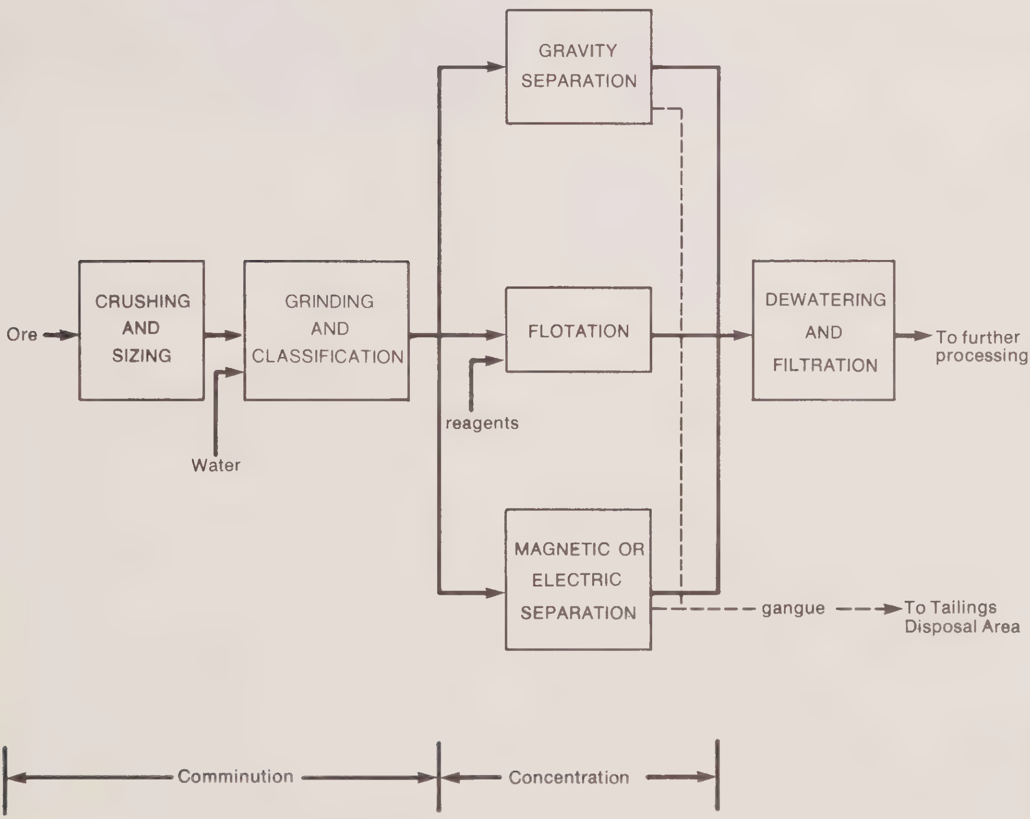
Source: Canadian Mining Journal, 1980.

katchewan Department of Mineral Resources, 1976). Although, this method is less expensive to build than conventional mines it has very high energy costs. Other solution methods involve the use of an acidic or alkaline leaching solution being injected into the mineralized zone through a series of drill holes.

Relative to surface mining, underground extraction is less disruptive of the land surface, particularly in those operations where waste rock is retained in the mine and applied as ground support to allow further extraction of the ore. Backfilling with waste materials is employed in the underground removal of approximately one-third of base metal ores in Canada (Ripley *et al.*, 1978). Where the rock is sufficiently strong, however, cavities are allowed to remain after the ore is removed and the waste rock is transported to the surface. This method is applicable to the mining of the remaining two-thirds of the base metal ores extracted.

Table 6 presents the volume of ore and waste rock hoisted from a number of representative underground metallic mines. The average waste rock disposal site at underground mines rarely exceeds 5 hectares (*see* Appendix II). The obvious environmental advantage of underground mining is the relatively small amount of waste rock that is accumulated at the surface. The main operations that affect the land surface during the extraction phase of mining operations are outlined in Appendix I.

FIGURE 9. GENERALIZED FLOW DIAGRAM OF THE BENEFICIATION PHASE



Source: Ripley, et al; 1978

Beneficiation

The purposes of beneficiation are either to yield the desired mineral product in finished form for immediate use by consumers (e.g. coal, asbestos), or to recover a concentrated product amenable to further processing by smelting and/or refining (applies mostly to base metal ores). The process (Figure 9) usually involves the alteration of the physical properties of the ore and removal of unwanted gangue in three steps:

(1) *Comminution* in which the ore is prepared by crushing and grinding;

(2) *Concentration* in which the desired ore mineral is separated from unwanted minerals (discarded as tailings or mineral waste); and

(3) *Dewatering* of the final concentrate prior to further processing using extractive metallurgy.

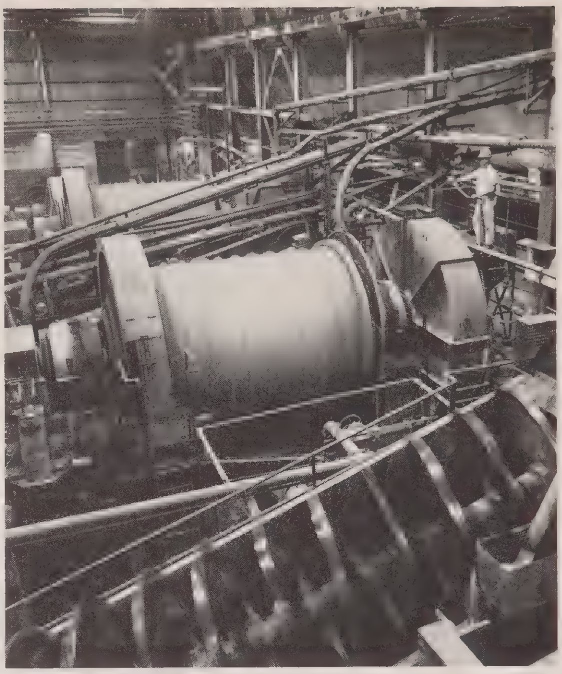
Comminution

Most ores undergo preliminary crushing (primary comminution) as part of the extraction phase. In the case of underground mines, the primary crushing is usually carried out underground, with the ore being hoisted to the surface, and dumped into a bin in the head frame. Secondary crushing and sizing is the first step undertaken in the mill during the beneficiation phase. The crushed rock is screened to separate it into size classes and then fed into a milling circuit where it is ground into a fine particle size (controlled by classifiers). The ground ore is then passed on for concentration.

Concentration

The product of a mill operation is a "concentrate" in which the percentage of valuable mineral is increased, and the material that is discarded is known as "tailings" waste. In the case of metals, the concentration process recovers the metallic minerals (e.g. sphalerite-zinc sulphide, chalcopyrite-copper-iron sulphide) rather than the pure metals (e.g. zinc, copper).

Two factors determine the effectiveness of a mill operation; the percentage recovery and the ratio of concentration. For example, in a daily operation, a mill that treats 1,000 tons of millheads (ore that is fed into the mill) assaying at 4 percent copper, will produce 60 tons of concentrate assaying at 60 percent copper. The ratio of concentration is 1,000:60 or 16.67:1. The recovery is calculated from the copper contained in the concentrate divided by that in the millheads, and is thus 36 divided by 40 or 90 percent. The four tons of copper unaccounted for was lost in the tailings, which should have a weight of 940 tons (excluding water).



Ball mill used to grind ore
NFB — Phototheque — ONF, George Hunter

There are four broad methods used in the concentration of mineral ores: gravity separation; flotation; magnetic or electrostatic separation, and hydrometallurgy. Another specialized, but little used, process is amalgamation.

(i) ***Gravity Separation:*** This is one of the oldest methods, but is not now widely used except for coarse ores of simple mineralogy, such as specular iron ores, and for ores that do not normally respond to flotation (coal, iron ore, some gold and silver, and asbestos). The effectiveness of the process depends on the difference in specific gravity between the ore and waste minerals (the greater the difference the better the separation). In order for the process to be effective the particles all have to be essentially the same size, hence uniform sizing is important. Very small particles are more effectively concentrated by flotation methods.

Jigs are the most commonly used method of gravity separation. The ore is concentrated in a screen submerged in water: either by reciprocating motion of the screen or by the pulsation of water through it (Northern Miner, 1968). Various types may be used in combi-

nation with other treatment processes. Coarse ore may be passed through jigs before flotation or cyanidation to remove grains of heavy minerals (e.g. gold or galena). This step saves the added expense and possible tailings loss that would be incurred if the coarse fraction of the material went through the complete process.

An "aspiration" process is used for asbestos in which the fibres, after being crushed and torn apart, are concentrated by being blown from the rock matrix by air currents.

(ii) ***Flotation:*** After comminution, the successive steps in a flotation cycle are conditioning, simple or differential flotation, settling, filtration, and sometimes drying of the concentrate. Flotation is the most widely used method in Canada and most commonly used for base metal-sulphide ores. In this process, the desired mineral particles are induced to become attached to air bubbles and float, while the others sink to the bottom of the flotation cells (Northern Miner, 1968). The valuable minerals are then concentrated and separated from the worthless gangue. (In some instances, in the non-metallic mining industry, the waste minerals are floated and the desired minerals are retained). Each mineral behaves in its own way with regard to adherence to air and water; the natural tendencies may be modified by introducing suitable chemicals to the pulp (a mixture of water and finely ground ore). The nature of the coating added to the mineral through immersion determines its susceptibility to flotation. The reagents used in flotation are classed as:

(a) Frothers: Pine oils and a large variety of alcohols are added to promote the formation and stability of bubbles.

(b) Collectors: Reagents added to the solutions in order to permit selective reactions. They promote the adherence of air-bubbles to the minerals. Xanthates and a wide variety of fatty acids are the most commonly used.

(c) Conditioners: These are added to modify the surface of the mineral particle and make it more susceptible (activators) or less susceptible (depressants) to concentration. Soluble chemical activators most frequently used to improve recovery of minerals are copper sulphate, lead acetate, or lead nitrate. Depressors such as sodium cyanide, sulphur dioxide, zinc sulphate, sodium silicate and any other organic compounds are used when the ore contains more than one economic mineral. The depressors are used for differential flotation allowing one mineral at a time to float, depressing all other minerals. This makes it possible to repeat selective flotation as many times as there are recoverable minerals.

(iii) ***Magnetic or Electrostatic Separation:*** Magnetic separation is a process by which a magnetically susceptible mineral is separated from gangue materials by applying a strong magnetic field (Northern Miner, 1968). It is used chiefly to concentrate or clean iron ores and for separating out other magnetic minerals that do not respond to flotation. It is used in reverse to purify non-ferrous ore by removing magnetic minerals.

The electrostatic process uses a high-voltage electric field to separate materials of different electrical conductivities. The procedure is limited to dry materials and is used with titanium-bearing alluvial deposits and iron ore (Ripley *et al.*, 1978).

(iv) ***Hydrometallurgy:*** This is a process in which water (or a water solution) is used to dissolve (or extract) the metallic compound and thus separate it from the remaining gangue (gold, silver, and uranium ores). The process is often called "leaching". In the leaching process, acids are used to dissolve metals from a concentrate or to recover metals from an oxidized ore. Some copper ores can be leached, using ammonia, ferric sulphate, or sulphuric acid according to the nature of the ore. This process is used at Gaspé Copper Mines Ltd. in Quebec as part of the milling circuit.

The "cyanidation" process applies to gold and silver ores only. Other base metals present in the ore are not recovered by this process. The alkaline solvent used is a weak solution of sodium or calcium cyanide which, when aerated, readily dissolves the precious metals. The metal is recovered by agitating the solution with zinc or aluminium dust. The precipitate is then collected on filters and refined by pyrometallurgical means. Some mines must concentrate the gold-bearing min-

Standard flotation cell
NFB — Phototheque — ONF, C. McNeill

Sink-float vat used to separate iron ore from waste rock
NFB — Phototheque — ONF, Paul de Groot

eral, usually those associated with pyrite by flotation before cyanidation (for example, the Dickenson Mine, in Ontario).

(v) ***Amalgamation:*** This is a process by which gold and silver are extracted by dissolving them in mercury. The process is suited only to ores in which the gold and silver occur in native (i.e. pure gold or silver particles) and fairly coarse particles. The precious metals are recovered by passing a layer of pulp over a table consisting of a plate of silvered copper which has been coated with mercury. The mercury holds and partly absorbs the particles of precious metal, while the gangue passes on.

Gold that is locked up in grains of pyrite or other minerals escapes recovery. Thus, in lode, amalgamation is chiefly used as an auxiliary process to recover coarse gold before cyanidation or flotation or to recover free gold from flotation concentrates. There are only three mines in Canada still practising amalgamation; all are in Ontario. With the present increase in gold mining however, some of the new or reopened mines may utilize amalgamation circuits as part of their milling process.

Dewatering

Final concentrates come from the flotation cells as a dilute slurry containing large amounts of water. In order to isolate the concentrate the water must be removed. The dewatering usually involves two processes; thickening and filtration.

(i) ***Thickening:*** This involves the settling of solids by gravity so that the excess water can be removed. Thickeners are settling tanks which separate the dilute slurry into a thick pulp and water. The usually circular tanks have a central feedwell, a periphera overflow rim, and mechanical bottom rakes which discharge the settled solids to an opening for discharge to an underflow for disposal, filtration, or drying (Boldt, 1967).

Since many of the finest and lightest particles do not readily settle they are flocculated with the aid of small quantities of chemical reagents, which cause them to cluster into flocs (loose liquid filled groups) and settle. Sometimes dewatering is achieved by using hydraulic cyclones which use centrifugal force to obtain separation, but this is employed only where low tonnages and minerals of high value are involved.

(ii) ***Filtration:*** This process is used to remove the bulk of the remaining water. Normally the fluid is passed through a line filter (usually a fabric) that traps the solid particles.

Despite the large amounts of water used in the beneficiation phase, the quantities of reagents utilized are small (usually less than a pound per ton of ore) and generally decompose when they are transported to tailings ponds (McKinsky, 1948). Most of the water, whether recycled or discarded to the environment, is held in a single pond or a series of ponds to allow for the settling out of the solid "tailings" particles. Tailings impoundment areas are generally built to handle large volumes of waste water as well as solid tailings. The retention of mill water and tailings in ponds provides the necessary time for decomposition of reagents and separation of the solids. Most important, in the case of base metal mines dealing with high concentrations of sulphide minerals, is that under acid-generating conditions the concentration of dissolved heavy metals in the supernatant can be excessive. Usually under these circumstances lime is added to reduce the acidity and to precipite the dissolved metals. Many mines recirculate treated water from the settling ponds back into the mill, for process water.

Dewatering an open-pit coal mine, Hinton, Alberta
NFB — Phototheque — ONF, Larry Monk

Beneficiation in Practice

In practice, the beneficiation processes utilized in Canada vary considerably, particularly between metallic, non-metallic, and energy-related minerals. There can be dramatic differences in the size of operations, land requirements, tonnage processed, final yield, and volumes of waste (*see* Appendix I). In the following sections, four types of mining products — metals, asbestos, coal, and tar sands — are discussed to illustrate the considerable variations.

Metallic Ores

The Lornex Mining Corp. Ltd. operates a large copper-molybdenum (Cu-Mo) open-pit mine at Highland Valley in British Columbia. The beneficiation process involves crushing, grinding, and flotation, with a total mill capacity of 43,500 tonnes/day (Collings, 1979). In 1979, 15.9 million tonnes of ore were milled, producing 206,962 tonnes of concentrates. The flotation process involves two circuits, a primary one producing bulk Cu-Mo concentrates and a secondary circuit which separates the copper and molybdenum. The dewatered bulk concentrate is conditioned with sodium hydrosulphate to depress the copper minerals and the molybdenite is floated with fuel oil in rougher cells and scavenger cells. The scavenger cells concentrate is returned to the conditioners and the scavenger tailing is the final copper concentrate (Reno, *et al.*, 1973). The rougher concentrate is processed separately in eight cleaner flotation steps to produce the final molybdenite concentrate. Over 98 percent of the ore milled becomes tailings waste.

An operation of this size had to dispose of 34 million tonnes/year of waste rock (quartz-diorite) and in excess of 15 million tonnes/year of tailings consisting of quartz, plagioclase (feldspars) and minor amounts of mica, chlorite, and calcite (Collings, 1979). The accumulated land area required to dispose of the waste rock and tailings was estimated at 369 and 345 hectares respectively (Murray, 1977*b*).

In British Columbia copper mines, the high volume of waste rock and tailings reflects the rather low grade of the ores mined. Most ore grades for copper are less than one percent, and in many instances they are even lower than 0.5 percent. In 1979, Collings reported that nine open-pit copper mines produced over 142 million tonnes of waste rock and 73.1 million tonnes of mill tailings. The land area required to dispose of the waste rock and tailings at the nine mines was estimated at 1,554 and 1,033 hectares respectively (Murray, 1977*b*).

Open-pit iron ore mines are the only other metallic mines that handled comparable volumes of ore. However, the chief difference is the grade of the respective ore bodies. Iron ore grades in the Labrador-Quebec area have a range of between 30 to 60 percent iron, compared to the less than one percent for British Columbia copper mines, hence the volume of waste rock and tailings produced is considerably less. But in recent years, new open-pit mines like the Mount Wright mine at Fermont, Quebec (Quebec Cartier Mining Co. Ltd.) which started production in 1975 are developing lower-grade ores in the 30 to 40 percent iron range.[3] The mining of lower-grade iron ores has meant an increase in the volume of ore handled, necessitating the use of larger beneficiation equipment, particularly in the comminution phase in order to reduce costs. (This was also true of the copper mines in British Columbia). Approximately 50 percent of the total ore milled at Mount Wright becomes tailings waste (Abbott, 1975). Autogeneous and semi-autogeneous grinding mills have almost doubled in size in order to handle the increased waste-to-ore ratio of the feed (Muloin, 1978).

At the Mount Wright mine, specular hematite (less than five percent magnetite) is first crushed to sizes less than 170 millimetres in diameter, subjected to autogeneous grinding, and then to primary gravity spiral concentrators with low-intensity magnetic separators which scavenge residual magnetite. The slurry is then separated according to specific gravity into concentrate, middlings, and tailings. The tailings are fed into cyclones with the water overflow being treated and recycled through the mill circuit. The process produces concentrates in the 65 to 68 percent iron range.

Although the mill capacity is 18 million tonnes/year (the second largest in Canada), the estimated 1979 production was 15 million tonnes of concentrates and pellets. A twenty-year tentative projection of production at the mine (at full milling capacity) expects that over 882 million tonnes will have been processed, resulting in an open pit of 464 hectares and 280 metres deep (Abbott, 1975). Waste rock and tailings areas are expected to require 480 and 218 hectares respectively. Total iron ore mill capacity in Canada at the time of the mine's opening was 78.3 million tonnes (Muloin, 1978).

By comparison, Dickenson Mines Ltd. operates a small underground gold mine at Balmertown, northeast of Kenora, Ontario. The beneficiation process involves

[3] The greatest tonnages of ore shipped from the region are in the form of beneficiated concentrates from 28-35 percent iron, rather than from the 50 to 60 percent range.

crushing, grinding, sizing, amalgamation, cyanidation, and flotation using pulp from the cyanidation stage (*see* Further Processing) (Malloy and Tapper, 1978). The mill has a maximum capacity of 450 tonnes/day with a total of 100,000 tonnes milled in 1979. There is very little waste rock, and tailings impoundment required approximately 30 hectares of land (Murray, 1977*b*).

Asbestos Ores

The asbestos milling process differs significantly from that followed in the treatment of other minerals, especially metallic ores. In Canada, crysolite is the only form of asbestos mined, and it is a fibrous form of serpentine, normally associated with massive serpentine. The recovery process is unique in that it usually involves separation of a fibrous mineral from a massive form of the same mineral.

The asbestos fibre has the same density and chemical composition as the host rock, advantage is taken of the physical difference of the rock and fibre after the latter has been released under impact and fluffed up in a dry state. In this state, the asbestos has a lower bulk density and is amenable to separation from the serpentine rock by screening and air suction.

The processed fibres are classified into five major groups according to fibre-length distribution. They are as follows: spinning fibre (Group 3); asbestos-cement (Group 4); paper fibre (Group 5); paper and single fibre (Group 6); and shorts (Group 7). These major groups are further broken down into about 30 grades according to fibre-length distribution. The actual grades are further divided according to other important fibre characteristics such as degree of fiberization or openness, cleanliness, and strength to meet the special requirements of the consumer.

There is no standard method of milling asbestos since each operation is designed to suit the rock from an individual deposit and must be flexible to meet varying conditions.[4] Hence detailed flow sheets and selection and use of equipment vary throughout the industry (Riley, 1978). However, the basic operations of crushing, drying, fibre separation, cleaning, fiberizing, and grading are common to all mills (Figure 10).

In terms of volume of ore mined and the amount of waste rock and tailings produced, the asbestos industry (8 producers with 14 mine-mill operations) in 1974 mined 94.3 million tons which resulted in 64.1 million tons of waste rock, 27.7 million tons of tailings and fibre production of 1.81 million tons. The largest asbestos mill in Canada is located at the Jeffrey Mine, operated by Canadian Johns-Mansville Co. Ltd., with a capacity of 33,000 tonnes/day (645,000 tonnes fibre produced in 1979). It is the western world's largest-known asbestos deposit. Tailings and waste rock combined accounted for 401 hectares in 1977 (Murray, 1977*b*). The estimated area covered by all asbestos waste rock dumps, and mill tailings was approximately 1,454 and 777 hectares respectively (Murray, 1977*b*). By comparison, the 10 underground potash mines in Saskatchewan have used a total land area of approximately 1,985 hectares for waste disposal of tailings (Saskatchewan Land Use Policy Committee, 1978). In both cases, the figures do not include future reserve areas, and/or sites occupied by such ancillary facilities as roads, power lines, loading facilities, repair shops, equipment yards, and storage warehouses.

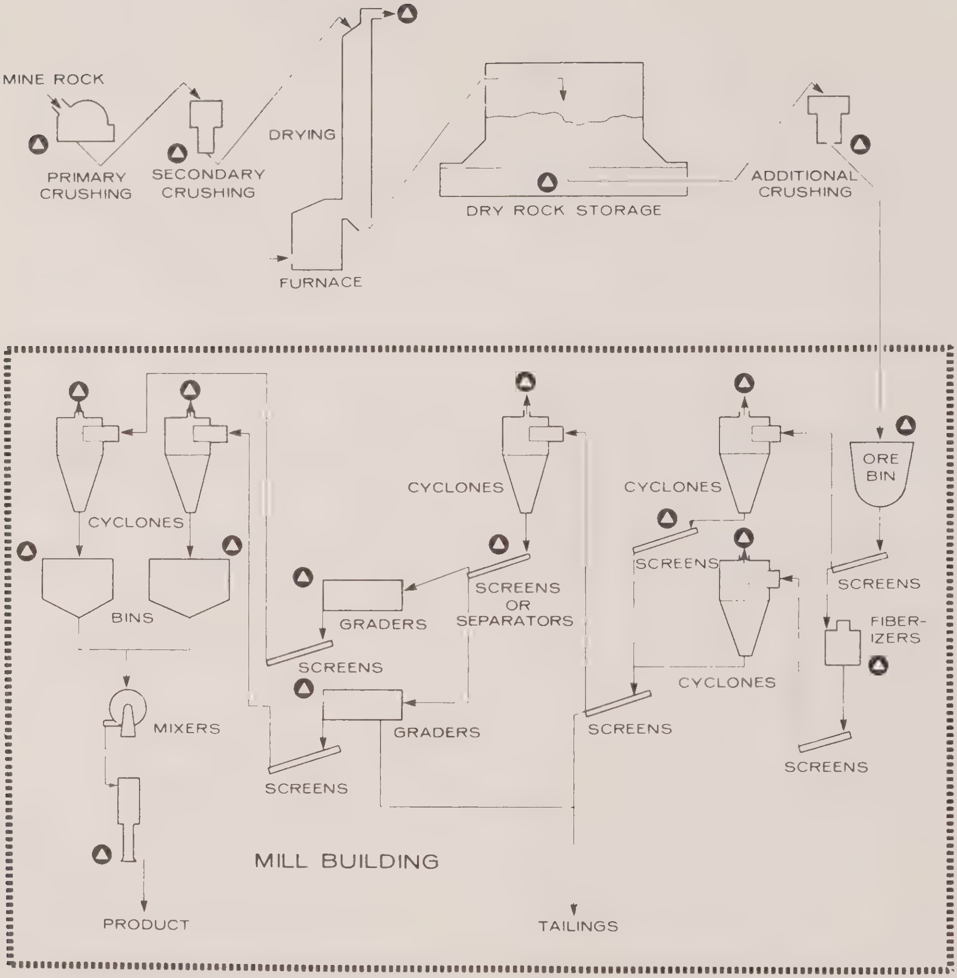
Coal

Coal beneficiation processes are similar to those used in the asbestos industry, but not nearly as complex, in that the nature of the preparation processes and degree of beneficiation required are determined by the coal's end use. Coal operations result in the removal of non-carbonaceous or ash-producing substances such as clay, shale, soil, and rock particles or sulphuritic materials from coal in order to meet consumer specifications with respect to calorific value, and ash and sulphur content. Two types of beneficiation processes are followed in Canada to achieve the various specifications, and are described below.

(i) ***Wet Process:*** The proportion of coal in "wet" preparation plants accounts for 94 percent of all beneficiated metallurgical and thermal coal in Canada. In principle, this process involves crushing, washing, and screening the coal and the use of gravity to separate the lighter coal fragments (lower specific gravity) from the heavier rock or sulphide mineral particles in an aqueous media. The sized and cleaned product is dewatered and air- or thermally dried prior to shipment to the consumer. If additional processing is required, coarse coal may be separated from the waste through the use of "jigs" in which the lighter coal is buoyed to the top of a flowing, agitated slurry containing coal, waste rock, and water; or heavy media cyclones in which the lighter coal is separated from the waste by being buoyed to the top of

[4] Asbestos fibres are distributed through the gangue matrix in veins varying in width from 0.4 millimetres to more than 25 millimetres. The length distribution of fibres usually varies in different parts of the ore body and between deposits. Tenacity of the bond holding fibres together, friability, and amount of impurities are also important factors .

FIGURE 10. FLOW DIAGRAM FOR MILLING OF ASBESTOS ORES



CONNECT TO EXHAUST AND AIR CLEANING SYSTEM

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a water/magnetic slurry. Intermediate to fine coal and waste particles (less than 6 millimetres and 0.6 millimetres respectively) are commonly separated on oscillating diester tables or in water cyclones and/or froth flotation cells in which the coal is floated in an air agitated slurry containing a frothing reagent and a "collector", commonly kerosene. This additional process is also followed by dewatering and drying.

Commonly, all process water is recycled within the plant itself or within a closed-circuit system for tailings impoundment. However, water losses through drying, in the shipped coal, seepage, or evaporation from tailings require replenishment from fresh water sources.

In general, all wet preparation plants produce three sizes of solid wastes, coarse (10 to 30 centimetres in size), intermediate, and fine "refuse" which, in addition to waste rock, may in total account for as much as 20 to 30 percent of the raw coal fed into the plant (Schmidt and Moffett, 1979). Classifiers separate out intermediate refuse from fine materials which are then dewatered and combined with the coarse refuse.

Refuse generated from all processes is collected and partially dewatered in thickeners from which it is pumped as a concentrate slurry to tailings or slurry ponds. The tailings pond supernatant may be recycled to the mill, allowed to evaporate or seep into the ground, or released into a natural body of water.

(ii) ***Dry Process:*** Less than seven percent of the thermal coal produced in Canada is beneficiated this way (at the mine sites or receiving thermal electric plants). In 1978, this represented 1.1 million tonnes of coal, of which nearly 50 percent was produced at two lignite mines in Saskatchewan.

In a typical dry process plant, the run of the mine coal is passed through grizzlies[5] situated ahead of roll-type crushers to separate the durable waste rock, tramp iron, and wood from the more breakable coal. Waste rock which passes through the grizzlies is rejected at the crushers. Following crushing, the desired sizes are obtained by passing the coal over decks of steel plate or woven wire vibrating screens containing the appropriately dimensioned openings. The current trend is to produce only two sizes of coal, the bulk of which is 50 millimetre lumps for power plant fuel. Undersized coal including fines is sold to domestic consumers or to the power plants, which as matter of course pulverize all of their coal.

Unlike wash plants, dry preparation plants do not generate much intermediate and fine coal refuse. In Alberta, the common practice is to dispose of this material by returning it to the mine area where it is combined with stripping waste and is eventually reclaimed. If the cleaning is performed at the power plant the refuse is disposed of with the bottom ash. In Nova Scotia where the coal is obtained from underground mines, the coarse reject material from dry preparation plants is disposed of in surface refuse piles.

Present annual coal production in Canada is approximately 30.3 million tonnes (thermal and metallurgical). Of this total 17.4 million tonnes (57.4 percent) are subjected to some cleaning or upgrading (beneficiation) at the mine site. Roughly 12.3 million tonnes, primarily Alberta sub-bituminous and Saskatchewan lignite, are not processed at the mine. Current preparation practices and provincial production data are summarized in Tables 7 and 8.

The tables indicate that all metallurgical coal is upgraded in wash plants. The combined total of metallurgical and thermal coal currently passing through wet preparation plants amount to approximately 16 million tonnes/year, or slightly over half the nation's total output.

Oil Sands

A schematic flow sheet of the Sunoco Ltd. (formerly Great Canadian Oil Sands Ltd.) beneficiation process showing the mass flow rates of the major input and outputs is illustrated in Figure 11. The extraction of bitumen from the tar sands utilizes the basic hot water or Clark process. The process makes use of the fact that sand particles are water wet and will tend to remain in the aqueous state when slurried with water. Elevating the temperature of the bitumen to about 85°C lowers the viscosity and density, allowing it to dislodge itself and float free from the water and mineral matter.

The beneficiation process involves a two-phase extraction process, followed by an upgrading phase that

[5] Grizzly: a grating (usually steel rails) placed over the top of a chute or pass for the purpose of stopping the larger pieces of rock or ore.

TABLE 7. CANADIAN COAL PREPARATION PRACTICES 1978 (tonnes X 10^6)

	Thermal		Metallurgical		Total	
Can. Prod'n. (Tonnes)	16.4		13.9		30.3	
	Tonnes	%	Tonnes	%	Tonnes	%
Washed	2.5	15	13.9	100	16.3	54
Dry Screened at Mine	1.1	7	-	-	1.1	4
No Preparation at Mine	12.8	78	-	-	12.8	42

Source: Aylsworth, 1979; Dep. Energy, Mines and Resources 1979a.

includes coking, production of synthetic crude oil and diesel fuel, and desulphurization (Plitt, 1978). In the "primary" extraction phase, oil sand feed is added to conditioners (water, caustic soda) in a rotating drum and sparged with steam, then passed over vibrating screens in separation cells. In this process, over 76 percent of the original oil sand feed is extracted as waste sand tailings (*see* Figure 11). "Final" extraction serves to remove the entrained water and solids from the bitumen. Froth from the primary extraction phase is heated with steam, diluted with naptha (to reduce viscosity and density of the hydrocarbons) and then centrifuged. The sand material removed by the centrifuge is re-pulped with water and pumped to the tailings pond. Slightly over 90 percent of the bitumen is recovered in the two extraction phases.

"The diluted bitumen is distilled to remove the previously-added naphtha dilutent which is recycled to the froth treatment plant. The bitumen is heated in a coking drum at about 500°C. The coke is deposited in the drum and the lighter hydrocarbons are fractionated into light gas, naphtha, kerosene and gas-oil. The light gas is desulphurized and used as fuel and for the production of hydrogen. The three liquid components are then charged to a hydro-desulphurizer where up to 99 percent of the remaining sulphur is removed. After upgrading, the three liquid components are blended together to form what is termed "synthetic crude oil"... "Approximately 65 percent by weight (70 % volume) of the extracted bitumen is transformed into "synthetic crude oil". The by-product coke is used to produce steam and to fuel a 70-megawatt power station. The excess coke (about 400 tons/day) is used for construction of drains in tailing dykes and stockpiled for eventual other uses." (Plitt, 1978).

The major waste problem associated with the beneficiation process is tailings disposal. Currently these wastes require a separately constructed tailings pond, however, as mining progresses, the mined-out area is to be used for tailings disposal. The tailings contain about 45 percent solids (mostly quartz) and about one percent bitumen. The coarse fraction is used for dyke construction. Sites for the disposal of oil sand tailings require exceptionally large surface areas. Simpson-Lewis *et al.*, (1979) state that: ***"from one ton ore of tar sands will occupy a volume of .6m³ as compared with a void space of .4m³ created by the mining. As a consequence of this volumetric discrepancy, the final elevation of a reclaimed***

TABLE 8. CANADIAN COAL PREPARATION PRACTICES BY PROVINCE, 1978

	N.S.	N.B.	Sask.	Alta.	B.C.
			(10^6 tonnes)		
Total Production	2.77	0.3	5.0	13.2	9.0
Met. Coal	1.33	0.0	0.0	4.1	8.5
Therm. Coal	1.44	0.3	5.0	9.1(1)	0.5(2)
			(Percent)		
Est. Met. Washed	100			100	100
Est. Therm. Washed	89	45		7	100
Est. Therm. Dry Screened at power plant	4	55	88	93	
Est. Therm. Prepared at mine	6		12	1	

(1) Combined total 8.5 million tonnes sub bituminous plus 0.6 million tonnes bituminous from Luscar Coal Valley mine to Ont. Hydro.

(2) Estimated 0.5 million tonnes bituminous from Byron Creek to Ont. Hydro.

Source: Aylsworth, 1979; Dep. Energy, Mines and Resources, 1979a; Environment Canada, 1979b.

mining area will be more than 18.2 metres higher than the original terrain."[6]

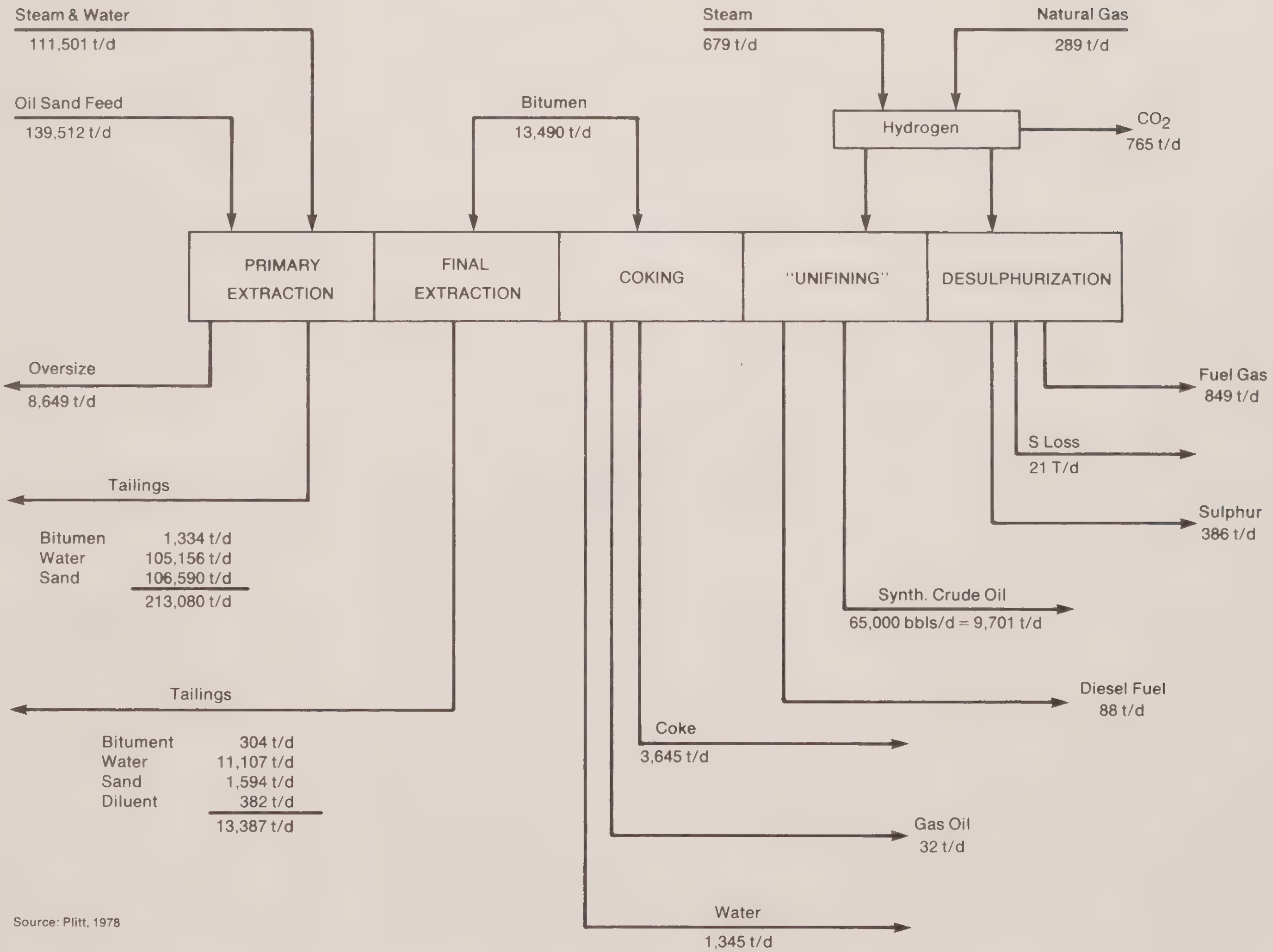
About five to ten percent of the tailings are fines (-44 microns) which settle slowly and tend to form a highly voluminous sludge. Their poor settling characteristics restrict the amount of pond water that can be recycled. Because of the high water content of the sludge (69 percent), the sludge retains fluid characteristics and must be stored behind dykes with little possibility of restoring vegetation over its surface. Hence there is a long-term problem of storing oil-laden sludge.

From the volumes of waste tailings, water, and bitumen discharged at each phase and the resultant end products (*see* Figure 11) it is evident that the tonnage involved in tar sands beneficiation processes (and the amount of land required to dispose of the waste tailings) far exceeds any other form of mineral processing.

The Suncor plant produces 65,000 barrels of crude oil from 139,512 tonnes of oil sand a day. The new Syncrude plant is almost double that size with a final product of 125,000 barrels/day extracted from an initial oil sands feed of 231,000 tonnes/day. It is anticipated

[6] In the case of the Syncrude Oil sands plant (15.9 thousand cubic metres per day) the initial tailings ponds will require an area of approximately 16 square kilometres and cover potential oil sand reserves of 111 to 127 billion cubic metres. (Simpson-Lewis *et al.*, 1979).

FIGURE 11. SCHEMATIC FLOWSHEET OF THE OVERALL SUNOCO OIL SANDS OPERATION



Source: Plitt, 1978

that an initial tailings pond of 23 square kilometres will be required for the first year of operations until tailings can be disposed of in the mined- out areas. However, given the problem with tailings sludges, it may be some time before a successful solution to reclamation is forthcoming. A third proposed plant (Alsands) will add a further 125,000 tonnes/day if approved, considerably increasing the amount of land affected in the Fort McMurray area (underlain by the Athabasca oil sands).

Further Processing

Whereas the beneficiation phase involves the mechanical and physical alteration of the ore, further processing or extractive metallurgy as the culminating phase of production, involves modification of the chemical nature of the minerals to isolate the metal from its sulphide or other compounds (e.g. oxides, silicates, carbonates). These operations are accomplished by "smelters" and "refineries", which are not normally associated with the mining complex itself, but are located to serve a variety of differing mining operations within a larger region and to take advantage of adequate transportation facilities for distribution of the final product.

The objectives of smelter operations are to reduce concentrates to metal in furnaces at very high temperatures, thus removing the bulk of the impurities. The refinery's purpose is threefold: first, it recovers the included precious and other metals; secondly, it obtains the pure metal for commercial use; and finally it removes any deliterious impurities that remain.

Methods of Smelting and Refining

The smelting and refining methods used to obtain a metal from a concentrate may be divided into the following broad groups:

(i) ***Pyrometallurgy:*** The process by which the metal is reduced from its sulphide through the application of high temperature in blast or reverbatory furnaces. The reaction is based on the declining affinity of a metal for oxygen, sulphur etc., with increasing temperature. In Canada, most of the ores treated this way are sulphides containing considerable amounts of pyrite and pyrrhotite.

(ii) ***Electrometallurgy:*** This process using electrical energy to disassociate the metal from its ore, is widely used for copper, lead, zinc, and nickel ores. Aluminium (bauxite from offshore) is processed this way at Kitimat, British Columbia and Arvida, Quebec.

In the "electrolyses" process, metals are refined by casting them into anodes which are placed in an electrolyte dissolved in water and the metal is then carried from the anode to build up on a cathode by passing an electric current into the system or similarly, by using an electrically inert anode and depositing a metal on the cathode from a purified solution of a salt of the metal (Northern Miner, 1968).

Although basically a pyrometallurgical process, "electrothermic" methods use electric retorts, electric arc furnaces, or induction furnaces. In this case it is the heating effect that is important. Electric arc furnaces in the steel industry are the best examples of this process.

(iii) ***Hydrometallurgy:*** This process is described under Concentration as it is normally carried out at the concentrator mine site rather than at the smelter.

Some metals may be recovered by one or other of these methods, while others may involve combinations of two, or perhaps even three, processes. Table 9 indicates the types of extractive metallurgical methods used for various ore types processed in Canada.

Further Processing in Practice

The fact that more than one metallurgical method may be required to extract a metal from its concentrate is illustrated in the following generalized example of copper smelting and refining.

Copper Smelting and Refining: Concentrates from the beneficiation phase will have a grade of approximately 28 percent copper. This is generally in the form of the mineral chalcopyrite, which also contains sulphur, iron, some silica. The concentrate is then transported to smelter where roasting, smelting, and conversion take place.

Roasting: is essentially an oxidation process, in which the sulphides are converted into oxides by heating the concentrates at high temperatures in the presence of oxygen-rich air. Part of the sulphur is burned off and part acts as a fuel. The final product of roasting is a "calcine", of which copper sulphide makes up the greater part. Copper content is increased modestly to around 33 percent.

Smelting: occurs when "calcine" from the roaster is mixed with flux and the mixture is fed into a "reverberatory furnace" operating at temperatures above

Pouring steel from open hearth furnace at Defasco Ltd., Hamilton, Ontario
NFB — Phototheque — ONF, George Hunter

Storage area at Coppercliff refinery, Sudbury, Ontario
NFB — Phototheque — ONF, Karl Sommerer

TABLE 9. EXTRACTIVE METALLURGY METHODS USED IN CANADA BY ORE TYPE

Ore Type	Metal	Extraction Method		
		Pyrometallurgy	Hydrometallurgy	Electrometallurgy
Quartz	Gold		X	
	Silver	X	X	X
Oxides	Calcium	X		
	Copper		X	
	Iron ore	X		
	Magnesium	X		
	Silicon	X		
	Thorium		X	
	Titanium	X		
	Tungsten		X	
	Uranium		X	
Sulphides	Antimony	X		
	Bismuth	X		X
	Cadmium			X
	Cobalt	X	X	X
	Copper	X		X
	Indium	X	X	X
	Lead	X		X
	Mercury	X		
	Molybdenum	X		
	Nickel	X		X
	Platinum metals		X	
	Rhenium		X	X
	Selenium		X	X
	Tellurium		X	X
	Zinc	X	X	X

Source: Ripley, et al., 1978.

1,100° C. The compositions of the fluxes are defined by the composition of the gangue minerals in the ore, for instance siliceous fluxes are used for ore high in calcium carbonate and vice versa.

The furnace forms two immiscible liquid phases:

(i) At the top, a liquid iron silicate "slag" forms when the fluxes react with the gangue minerals; and

(ii) At the bottom, a fused mass called a "copper matte" forms containing the copper, most of the iron, and both in chemical combination with the sulphur.

The "matte" produced also contains any precious metals that may have been present. The slag is removed and sent to a dump and the remaining copper now grades at about 45 percent.

An indication of the volume of slag produced is illustrated by INCO's Sudbury copper smelter operation (International Nickel Co. of Canada, 1976). The solid charge added to their oxygen flash furnaces is 1,500 short tons per day of copper concentrate and 220 short tons per day of flux. The furnace produces 920 short tons per day of copper 'matte' and 620 short tons per day of 'slag'. The estimated area occupied by the slag disposal site in 1976 was 243 hectares (Murray, 1977*a*).

Conversion: Begins with the transfer of the matte to a copper "converter" (furnace) along with more flux and reducing agents. Here the iron/copper-sulphide matte is oxidized to blister copper by blowing air through the molten material, while the iron sulphide oxidizes to sulphur dioxide and iron oxide. The sulphur dioxide leaves the converter and is collected in a sulphuric acid plant. The iron oxide reacts with the fluxes (silica) to form an iron silicate slag which is recycled to the matte smelter for recovery of residual copper. Air is reintroduced to the converter to oxidize the copper sulphate, and the resulting sulphur dioxide is collected in precipitators. That which escapes or misses the precipitators goes 'up the stack'. The resulting "blister copper" is approximately 98 percent pure.

Refining: Blister copper pigs go through a refinery process to purify the copper and/or to recover the precious metals which remain. In Canada, most refining is by electrolysis since pyrometallurgy cannot reclaim residual amounts of gold, silver, selenium, and telurium, etc. Electrolytic refining also produces very pure copper.

In electrolytic refining, copper plates serve as anodes and are placed in electrolyzing tanks containing a solution of copper sulphate and dilute sulphuric acid. Thin sheets of pure copper are also placed in the same tank to serve as cathodes. An electric current is passed through the system and copper is carried from the anodes to build up on the cathodes in a very pure form. The cathodes are eventually removed and melted down for casting into commercial shapes. The inactive impurities such as gold and silver fall from the anodes to the bottom and become part of what is called anode mud, which is recovered and refined in a separate process to recover the metals.

In pyrometallurgical refining, the blister copper pigs are melted again in reverberating furnaces and air is blown through it oxidizing some of the impurities and forming "set" copper containing oxygen. The "set" copper is then poled to remove the excess oxygen.

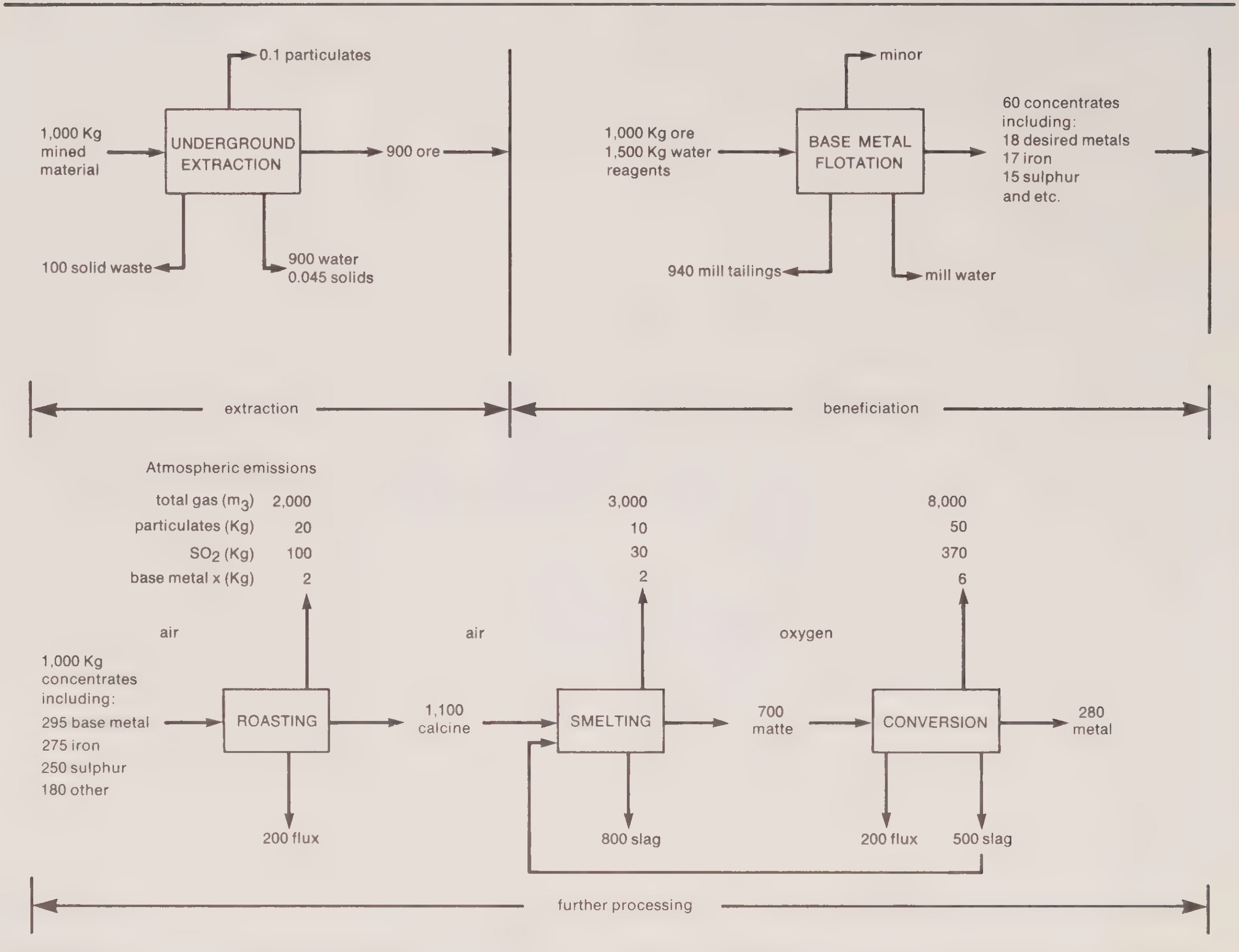
Pouring copper anodes
NFB — Phototheque — ONF

The major residual waste of the further-processing phase is that of smelter and refinery slags, but, compared to the production of mill tailings in the beneficiation stage, the quantities generated are approximately 1/15th of those of the tailings by weight (Ripley *et al.*, 1978). The slag typically contains one third of each of metallic oxides, silica, and iron oxides (Dennis, 1965). Unlike mill tailings, slag is generally more physically stable and chemically inert, and, the waste quantities involved are relatively small, it causes less environmental damage. Consequently, its disposal is less of a concern, in that land requirements are small. Due to their inertness and generally stable structure, slags are widely used for construction material, thus reducing the eventual size of disposal area required.

Mine Wastes

A composite and generalized materials flow diagram for the extractive, beneficiation, and further-processing phases of a typical base-metal mine operation is illustrated in Figure 12. Although the average percentage of waste illustrated may be somewhat misleading as there are wide variations throughout the industry, it provides an indication of the range and amount of waste generated throughout the production stage of a metal with respect to the nature of the ores mined. Nevertheless, the residuals released to both the atmosphere and hydrosphere are fairly typical, as are the volumes of solid waste. Table 10 outlines the major wastes generated and their chief characteristics. Included in this table are sludge and slime wastes produced as a result of air and water pollution control

FIGURE 12. COMPOSITE GENERALIZED MATERIALS FLOW DIAGRAM FOR THE EXTRACTIVE, BENEFICIATION, AND FURTHER PROCESSING PHASES OF A TYPICAL BASE-METAL MINING OPERATION



Source: Ripley, et al; 1978

TABLE 10. CLASSIFICATION AND CHARACTERISTICS OF MINERAL WASTES

	TYPE		
	OVERBURDEN	GANGUE OR WASTE ROCK	MINE AND MILL TAILINGS
DESCRIPTION	Material that must be removed to expose the bedrock or ore body. Usually consists of soil, sand, clay, shale, gravel, boulders, etc. Usually excavated by dragline, scraper, bulldozer or other earth moving equipment, transported and dumped, usually in ridges, cones, or long slopes.	Coarse graded material other than overburden of no present value that must be broken and removed during metal and non-metallic operations to obtain the ore. Often removed together with overburden and disposed of in waste dumps. Usually fairly homogencous for each mine operation but can be quite different from one mine to another, even when the same type of ore is mined.	Tailings are finally sized particles that are discarded following the concentration and recovery of the desired mineral values from metallic and non-metallic ores. Normally handled as a water slurry which is transported by pipeline or flume and deposited by natural settling into artificial ponds created by damming or into a natural water body or a combination of the two. Effluent is decanted, treated and may be recycled into the mill.
CHARACTERISTICS	Heterogeneous and unconsolidated. Consists of two components: 1) Pedogenic topsoil that has undergone oxidation and weathering, forming a layered-profile structure, with vegetation growing on it. 2) Surficial (subsoil) unaltered material not presently undergoing weathering or oxidation (soil forming factors). Little or no organic matter; doesn't support plant life. Surface cover removed in coal strip mines; sand and gravel pits; tar sands extraction, etc.	Variable in size, due to variations in ore formations and different mining techniques. Size ranges are from boulders down to gravel. In general, all sources of waste rock can be reduced to a desired gradation by normal crushing and sizing methods. Some waste rock may still have a low grade metal content which may be considered as a potential resource in future.	Mineralogical composition generally corresponds to that of the parent rock from which the ore was derived. Difficult to generalize on characteristics due to wide range of source rock types and processing techniques. Most tailings are composed of hard, angular siliceous particles with a high percentage of fines (40-90% passing a 200 mesh or .074 mm sieve). Usually more than 90% of the original ore remains as tailings after the milling process. Range from sand to slime sizes but are sometimes larger; may include sulphides. Widespread throughout base, ferrous, precious metal mines, and non-metallic mineral operations.
POTENTIAL USE AND PROBLEMS	Road fill, construction, landscaping, reclamation purposes, dams, drainage channels. May be low in plant nutrients, organic matter, and can be acidic or have texture and salinity restrictions.	Occasionally used as fill or for earth embankments, only significant potential use is for construction aggregate. Mine backfill, road fill main uses.	Potential source of metal and mineral values, eg., gold, silver tailings, raw materials for construction materials, fertilizer, additives, mineral fillers and chemicals. Coarse tailings used for mine backfill, paving mix, embankments.

TABLE 10. CLASSIFICATION AND CHARACTERISTICS OF MINERAL WASTES (Cont.)

	TYPE			
	COAL REFUSE	QUARRY WASTE	METALLURGICAL SLAGS	WASHERY REJECTS: SLUDGES, SLIMES
DESCRIPTION	Reject material that results from preparation and washing of coal. It is usually produced and disposed of in a coarse and fine form. Coarse refuse (100 m to 2 mm particle size) is found as a solid, while fine refuse (less than 2 mm particle size) is discarded in a slurry form.	Unwanted material from stone quarries, sand and gravel pits, consisting of a variety of waste from excavation, blasting, crushing and sizing operations.	Molten by-products from smelting and refining of metallic ores, particularly iron and steel, copper, lead, nickel, and zinc. Three types: blast furnace, steel and heavy metals.	Generated from processes in which large amounts of water are used, resulting in slurries with low solids contents. Following disposal in holding ponds, these wastes contain significant levels of water, even after prolonged periods of drying. Also unstable solids produced by washing of gaseous wastes and metallic products. Especially those that result from scrubbers and cyclones used in dust control.
CHARACTERISTICS	Consists of varying amounts of slate, shale, sandstone, siltstone, or clay type minerals which occur in or adjacent to the coal seam, as well as some coal which was not separated during preparation. Coal wastes may contain a certain amount of sulphur-bearing minerals, which result in acidic discharge when exposed to water and air. Potential acid generating wastes occur in the Atlantic Provinces.	Heterogenous and unconsolidated, wide variety of reject material including topsoil, subsoil, poor quality stone, reject material from crushing and screening operations, and dust collected from baghouses or cyclones.	Blast Furnace Slag: is the non-metallic byproduct, consisting essentially of silicates of lime and other bases. Air cooled slags are most common; light, hard, angular, interlocking particle shape, highly durable and resistant; a good aggregate source. Steel Slag: Three types: oxygen, electric arc and open hearth. Slags are generally resistant to abrasion; angular and vesicular, denser than blast furnace slag, and air cooled. Steel slags tend to expand due to unslaked lime content which hydrates quickly. Base metal slags: air cooled or granulated copper, lead, zinc slags characterized as ferrous silicates; nickel as calcium or magnesium silicates.	Solid wastes are usually in a sludge form. Slimes have very low solids content, settlement rates are extremely slow. Hence are of very limited use.
POTENTIAL USE AND PROBLEMS	Little or no potential use developed. Land fill, landscaping, and some construction purposes. Some being reworked to recover coal for power plant fuel (e.g. Stellarton, N.S.)	Miscellaneous fill on or near site. Topsoil and overburden for landscaping, screening berms, or reclamation/rehabilitation.	Blast furnace slag widely used as an all purpose construction material. It and others used for highway surfaces, asphalt binders, land fill, and structural fill, etc.	Limited use to date.

Sources: Collings, 1975; Murray, 1977a; and Collins and Miller, 1979.

technologies. On average, of the total quantity of ore extracted in metallic mines, only two percent comprises the values for which the ore was mined. Percentages for specific examples are copper 1.13, nickel 1.41, lead 2.08, and zinc 5.11. The remainder is discarded as wastes, 50 percent as waste rock, 44 percent as tailings and 4 percent as smelter slag (Ripley *et al.*, 1978). In general, considerably more material must be extracted to recover the scarcer minerals, the waste involved being correspondingly higher.

This is especially true for many of the non-metallic mines where the wastes generated in the beneficiation of coal can reach 35 percent, 59 percent for potash, 98 percent for asbestos, and 99 percent for uranium (Ripley *et al.*, 1978). The problems involved in the disposal of mill tailings are further aggravated by the decrease in density and corresponding increase in volume of the original material as it proceeds through the beneficiation phase. This has been further compounded by the increasing use of open-pit mining to extract lower-grade ores which generate even more waste for disposal. This is particularly evident in British Columbia where the annual production of waste rock and tailings (not including sand and gravel and placer mining) now exceeds 300 million tonnes (Collings, 1979). By comparison, Quebec produced 140 million tonnes and Ontario 80 million tonnes of waste rock and tailings (Collings, 1975, 1977). The three provinces combined produced over two-thirds of the Canadian total of over 800 million tonnes (Collings, 1979).

In 1977, excluding sand and gravel pits, open-pit mine operations accounted for 64 percent of all mines in British Columbia. The reverse was true for Ontario, where 60 percent of the mines were underground, 75 percent in case of metallic mines alone (the same figure applies to Quebec metallic mines).

The significant difference between Quebec and Ontario is the large tonnage of waste rock and tailings produced at the open-pit iron ore and asbestos mines. The increasing use of open-pit methods for metal extraction and strip or open-pit methods for coal will continue to lead to much larger land requirements for mine operations and a wider influence on neighbouring land uses. In addition to the large volume of mine wastes accumulated each year, over 4.55 billion litres of water are used daily in mine operations across Canada presenting difficult contamination problems associated with seepage water and sludge separation in tailings ponds (Mining Association of Canada, 1979). Appendix II provides data from two separate studies on mine wastes, indicating the average area occupied by mine wastes and open pits at Canadian mine sites.

Coal preparation plant, Fording Coal Ltd., Elkford, British Columbia
I.B. Marshall, Environment Canada

Waste Utilization

Of the huge quantities of wastes being generated from the mining and mineral processing activities in Canada, the majority have been disposed of in aesthetically unattractive dump sites, often with potential for degrading the environment. Therefore, any attempt to utilize even a small portion of these mineral wastes would contribute to an overall reduction of environmental problems associated with disposal and would aid in the conservation of mineral resources by reducing future demands placed on presently unextracted mineral reserves.

Interest in utilizing waste products from mining is not new, but it has received increased attention in the past decade. Much of the earlier attention was in the United States where it came to prominence in the early 1960's after initial studies began as early as the 1920's (Collins and Miller, 1979). Collings (1975) pointed out that in Canada several factors stimulated interest into researching the technical and economic feasibility of utilizing mine wastes, including: concern over developing energy shortages, with its attendant cost increases; rapid consumption of non-renewable resources, particularly those in more favorable locations; increased processing and transportation costs; legislation restrictions on mining near urban centres; and, finally, the environmental pollution effects of waste disposal.

However, the actual identification and development of viable uses for mineral wastes is a complex problem that normally comprises the following stages (Down and Stocks, 1977):

(i) To locate, quantify, and typify the wastes;
(ii) To determine the existing uses, if any;
(iii) To examine the technical problems of using the waste in a manufacturing process, and to determine the cost of the products and their ability to meet specifications;
(iv) To investigate the techniques and economics of value recovery; and
(v) For the products or values obtained, to determine the regional demand which may exist for them, and the economics of satisfying that demand, particularly in view of competition from established materials.

In the late 1960's, the Mines Branch (now the Canada Centre for Mineral and Energy Technology) initiated studies on the utilization of mine wastes. By 1971, a mineral-wastes inventory was started to identify, characterize, and evaluate primary mineral wastes by the Mineral Sciences Laboratory of CANMET (Collings, 1979). This program was expected to be completed by the end of 1980.

At present, only a very small percentage of the mineral wastes are being utilized in Canada for the following purposes: as bulk fill; as a source of crushed and sized aggregate; or as a source of valuable minerals unrecovered in the beneficiation and further processing phases (*see* Table 10).

Most of the waste materials used at this time are limited to local uses, due largely to the high costs associated with transportation, and to the remote location of most mines. Other important economic factors affecting their use are the value of the material, cost of competitive materials, market demand, comparative costs of disposal, and adverse environmental consequences of their use.

At the mine site, waste rock is used as unaltered backfill, landfill, or for road construction. In the case of underground mines, most is consumed as mine backfill due to the small amounts generated. In a recent survey of mining (Canadian Mining Journal, 1980), out of 49 underground mines responding, 16 reported no waste rock, and of the remaining 33 only six percent of all the material extracted was waste rock. Many of these underground mines use the waste rock and tailings as backfill in mined out stopes. Waste-rock disposal sites rarely exceed 5 hectares at underground mines while those at open-pit mines are generally in excess of 75 hectares (*see* Appendix II). Large volume uses of waste rock at open-pit mines are rare.

The recent report on mineral wastes in British Columbia (Collings, 1979) reveals that waste rock from a former open-pit iron mine (Texada Island) is being sized and barged to Vancouver and sold as railway ballast and concrete aggregate: rock from Cominco's Sullivan concentrator is used as railway ballast; and the Granby Corporation's Phoenix mine is extracting unrecovered copper averaging 0.15 to 0.25 percent from waste rock due to exhaustion of ore reserves in its open pit.

In addition to mine backfill, the coarser sand fractions of mill tailings can be used as construction materials provided that there are no potentially harmful contaminants in the tailings. Other uses for tailings are limited by their lack of cohesion and their susceptibility to erosion. Some tailings are being reworked for their gold content after prices escalated in the past two years. Similarly, Texasgulf began stockpiling pyrite concentrate at a rate of 500,000 tons/year in Timmins for potential future use (Collings, 1975). Tests continue to

be conducted on asbestos tailings since they contain five to ten percent of short asbestos fibres with significant amounts of magnesium, nickel, chromium, and iron (Collings, 1977).

Ultimately all wastes that cannot be economically recycled are discarded permanently by accumulation on the earth's crust or by land filling. The form of disposal taken varies significantly and the consequences can be environmentally acceptable or disastrous, depending on the techniques and the management practices used during and after the final closure of mine operations.

The continued adverse environmental effects associated with problem wastes such as acid mine drainage, sulphide-based tailings, asbestos particles, leaching of heavy metals, or radioactive hazards of uranium tailings all require that long-term precautions be set in motion during the production stage for the eventual safe abandonment or reclamation of the mine site. Williams (1975) included the following basic precautions in dealing with the safe disposal of mine wastes:

- (i) Protecting the quality of groundwater from degradation by leachates emanating from and passing through waste piles;
- (ii) Protecting surface water from silt and dissolved solid loads generated by erosion and corrosion of waste piles;
- (iii) Prevention of aeolian erosion with concomitant down-gradient dust problems; and
- (iv) Protecting human life from catastrophic failure caused by floods or seismic events.

Much of the waste disposal problem is handled by long term, planned stabilization and reclamation or rehabilitation procedures in the post-production stage of mining.

POST-PRODUCTION STAGE

Mining activities have a major impact on the quality of land resources and, thus, on the value that people derive from them. In the absence of adequate provision for protection of off-site damage and subsequent mine reclamation, the land affected is diminished in value or lost from future alternative uses. Public concern about the effects of mining and the potential loss of further environmental resources has led to a considerable change in the duration and scope of the mining process in the past decade. Much of this concern has been translated into added regulatory requirements for environmental protection and resource management in the post-production stage. Although mines have always been responsible (to varying degrees from province to province) for the condition in which the mine site is left on closure, much of the effort in the past resulted in a general clean-up or minimum health and safety standards being met.

Today, most provincial and territorial requirements for reclamation have placed the responsibility on operators to return formerly mined lands into some viable post-mining use or aesthically pleasing condition. Although some operators still believe that reclamation is not an integral component of the mining process, as a consequence of the new legislation, it has become integrated into both the pre-planning and operational stages of mining. Accordingly, if concurrent reclamation is practised, it can be carried out effectively and at lower costs than if it is considered as a separate part of the mine closure phase. The requirements that incorporate close-out plans into the pre-production stage have resulted in these plans sometimes being referred to as 'designs for final abandonment'. These plans are a response to regulatory requirements or suggested guidelines and are no longer a matter of mere cosmetics once the mining is completed.

Today most reclamation programs are implemented for the following reasons (Falkie and Saperstein, 1971):

- (i) <u>Potential for Multiple Use</u>: To avoid the loss of surface value intrinsic to the land.
- (ii) <u>Avoid Public Displeasure</u>: To make the mine site as palatable as possible to neighbours. Reducing the extent of impacts, coupled with good reclamation and conservation techniques are important factors in reducing opposition to mining developments.
- (iii) <u>Aesthetics and Work Conditions</u>: Improve working conditions on the site for employees.
- (iv) <u>Engineering and Pollution Control</u>: To stabilize dangerous slopes, reduce erosion, sedimentation, pollution, etc.

Temporary Mine Closure

When a mine is shut down due to adverse market conditions and the entire operating facilities are left on the property it is usually considered a temporary shutdown. Under these circumstances, all equipment and buildings are maintained in working condition by the companies in anticipation of reopening operations. Health and safety precautions are paramount, normally including the following maintenance requirements:

- (i) Open pits and underground shaft entrances be fenced in or protected from public access;
- (ii) Disturbed areas be left from all hazards such as unstable slopes, explosive or toxic compounds;

(iii) Mine site be left in a state free of debris, garbage, equipment, or other materials;

(iv) Waste rock dumps, tailings, and settling ponds be maintained in a hazard-free state, including maintenance and stabilization of all tailings pond dykes or containment facilities. Where necessary, the angle of repose of waste dumps be reduced to a stable angle or other stabilization techniques be used (sealants, revegetation);

(v) Where wind and water erosion from waste dumps, tailings, and stockpiles is evident stabilization techniques should be introduced including sealants or revegetation depending on the length of closure or regulatory requirements; and

(vi) Where it is not possible to stabilize an area, provisions should be made to contain and treat contaminated drainage for as long as such contamination occurs.

Monitoring provisions established during the operational stage of mining should be maintained. They normally include mine drainage; residual mill process effluents; contaminated surface drainage; seepage from ponds, impoundment areas, waste dumps; tailings dumps, and stockpiles; erosion and sedimentation; any adverse changes to aquatic and terrestrial ecosystems; and appropriate measures taken to seal or eliminate sources of contaminated drainage or airborne pollutants.

The extent to which these precautions are instituted will depend on the individual requirements of the provinces in the first instance, and federal regulations where applicable. In many cases, the use of revegetation as a means of stabilization and aesthetic enhancement may prove impractical and costly in situations of temporary closure. This is particularly true in the case of waste rock and tailings dump sites which are going to be reactivated.

Permanent Mine Closure

Permanent closure of a mine usually occurs when ore deposits have been exhausted and all mining activity has ceased. Occasionally a mill complex may remain active, serviced by new mines within the region. However, the potential for continued environmental disturbance and pollution problems still exist if the mined lands are abandoned without adequate environmental precautions taken to clean up and reclaim disturbed lands, open pits, underground workings, waste rock dumps, tailings areas, impoundment ponds, man-made structures, and altered or disturbed drainage networks.

The prime objective of final abandonment is to find the best means available to ameliorate all of the deleterious effects that mining activities have had on the land and water resources both within and around the mine site. Many of the potential problems can be handled readily in the general clean-up phase, but the bulk of the attention will focus on reclamation measures. The reclamation of land always has beneficial effects on water quality and public well-being.

The formal integration of reclamation into the mining process has been relatively recent in Canada — initiated by regulatory requirements in the late 1960's and early 1970's. In essence, the status of reclamation has changed from that of a clean-up operation after mine operations have ceased to being a major component in the overall design of future mine developments. In the case of surface strip and some open-pit mines (e.g. coal), the co-ordination of the mining and reclamation plans are essential, since vast tonnages of waste overburden has to be selectively removed and replaced in order to reclaim to a productive post-mining use.

Regulations now require that reclamation plans start soon in the life of a mine, often in the form of experimental work; stabilization and safe placement of wastes; and an overall program to minimize physical and chemical degradation of the land surface. In most cases, the costs of reclamation are borne by the mine operator and therefore become part of production costs. Therefore, mine operators should develop and cost a planned approach to reclamation of the mining site based on the anticipated life of the mine at the time of development (Fisheries and Environment Canada, 1977).

Through the issuing of guidelines or standards under the various regulations or Acts requiring the clean-up and reclamation of abandoned mines, reclamation plans have become considerably more complex and extensive than those of a decade ago. Appendix IV provides two provincial examples of the basic requirements now considered essential for all mine abandonments. The first example deals with reclamation guidelines for metal-mine abandonment issued in British Columbia under Section II, of the Mines Regulation Act (British Columbia, Ministry of Energy, Mines and Petroleum Resources, 1979), including general requirements for overall clean-up, tailings ponds, waste dumps, and pit areas. The second example provides reclamation criteria recommended for surface disturbances in Alberta.[7] The main focus of the criteria is

[7] These criteria are issued as part of 'Guidelines For the Reclamation of Land In Alberta' issued by the Land Conservation and Reclamation Council of Alberta, in 1977.

directed towards coal-strip (or open-pit) mining (to a lesser extent mineral aggregates) and are to be used for guidance in formulating reclamation plans.

Some of the basic assumptions identified in the guidelines and criteria are that voluntary pre-planning to minimize land disturbances will be undertaken as a matter of course. In addition, it is assumed the proponent has assessed potential environmental problems and effectively incorporated proper environmental practices in planning the field operations. A program of observation and experimentation is expected to be conducted, employing the best applicable technology to determine the most satisfactory methods and techniques of development and reclamation. In some provinces additional reclamation objectives for specific land uses have been suggested. For example in Alberta draft requirements for agriculture, timber and wildlife habitat have been outlined (Alberta Environment, Land Reclamation and Conservation Division, 1977, Pers. Commun.). The importance of the new regulations, guidelines, and standards is that the post-production stage can no longer be relegated to a clean-up operation. Indeed, reclamation has become the focus of attention for the design of the entire abandonment program.

Reclaimed coal mine overburden spoils, B.C. Coal Ltd., Sparwood, British Columbia
I.B. Marshall, Environment Canada

Land Reclamation

Frequently the terms reclamation, rehabilitation, restoration, and re-vegetation have been used synonymously to describe clean-up and improvement work done on disturbed lands. *Reclamation* has been interpreted in this study to include any process that promotes soil conservation and productive use of degraded or disturbed land. Reclamation implies that the site is made habitable to organisms that were originally inhabitants (National Academy of Sciences, 1974), and includes any treatment which is not restoration.

Restoration is defined as recreating the original topography and re-establishing the previous land use (Down and Stocks, 1977).

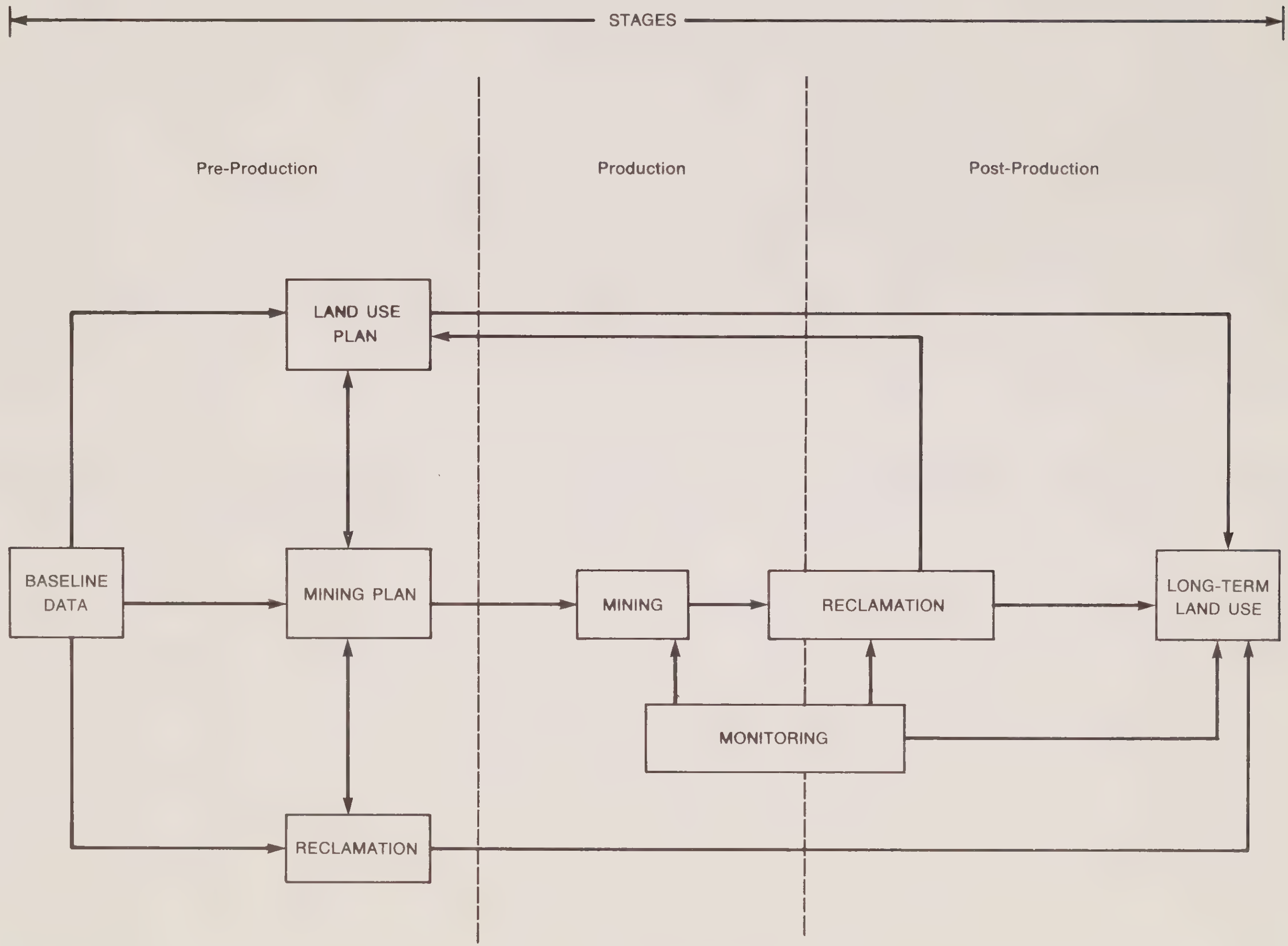
Rehabilitation implies that the land will be returned to a form and productivity in conformity with a prior land use plan including a stable ecological state that does not contribute substantially to environmental deterioration and is consistent with surrounding aesthetic values.

Generally there are only three options for the actual management or reclamation of mined lands (Cairns, 1979):

(i) To do nothing and leave the land as it was when the mining was completed. This option has become socially and economically unacceptable, and some form of reclamation is now required in all provinces and territories. In many instances, disturbed lands can be rehabilitated to provide a base for various renewable resources. More importantly, the potential offsite impacts of abandoned mine lands may result in long-term degradation of neighbouring land and water resources.

(ii) To restore it to its original condition. Restoration as a viable second option is almost impossible to achieve, for both technical and economic reasons. It also limits the option of an alternative land use that may be more preferable than the original. Full restoration to an original condition given current knowledge and experience may even be possible but it may take decades to achieve the same level of productivity. The drawback of this long-

FIGURE 13. SCHEMATIC ILLUSTRATION OF THE "STATE OF THE ART" APPROACH TO THE ROLE OF RECLAMATION IN THE MINING PROCESS



term option is the difficulty in achieving political and economic support for such long-range benefits, when immediate results have become the norm of society, reflected through existing statutes and regulations.

(iii) To reclaim it to an ecologically improved and more socially acceptable condition. It is not surprising that this has become the one most widely accepted option in Canada. However, demands for "full restoration" are required under certain circumstances, especially with regard to former agricultural lands. The third option embraces elements of both reclamation and rehabilitation. However, it is difficult to separate the two since most statutes and regulations in Canada use the term "reclamation", but define the conditions required under it as though it were, in fact, "rehabilitation". Reclamation may include any or all of a number of procedures including landscaping, soil amelioration, revegetation, and chemical/physical stabilization.

Option one may be acceptable when past evidence of former abandoned mines in similar ecological conditions indicates that they have recovered under natural conditions or with only limited assistance. This assistance may be through a cover crop or sealant to prevent erosion while native species capable of living under the new conditions establish themselves. This may be the ideal situation for remote, isolated sites that present no environmental hazard or requirement for aesthetic upgrading.

Planning

Before 1970 in Canada, there were few instances where reclamation plans were formulated prior to the actual construction and operation of a mine. The requirement for reclamation plans to be submitted along with applications to build a new mine was initiated towards the end of the 1960's.

Even with early planning reclamation cannot proceed until the mine and/or mill complex actually closes down. However, the early planning allows for the practical storage of topsoil (overburden) and careful placement of wastes, to complement the final post-mining reclamation plan. At the same time, planning provides for the setting-up of adequate testing programs (revegetation, drainage, slope stability, materials) to meet specific land use objective (when required).

The current "State of the Art" approach to the role of reclamation in the mining process is illustrated in Figure 13. The actual on-site practices followed in each of the stages however differ in accordance with the nature of the land to be reclaimed and the respective provincial regulatory requirements.

In the pre-production stage the early emphasis is on baseline data collection for analysis and subsequent development of mine production, reclamation, land use, and monitoring plans for the project (Figure 14). The baseline data requirements for the actual production plan have been dealt with earlier in this chapter. The additional data requirements for the environmental assessment, reclamation, and land use planning generally require consideration of the following; topography, soils and surficial deposits, geology, hydrology, biology, climate, socio-economic and historical aspects, land use, regulations and zoning, and permit approval processes.

These factors, coupled with the physical and economic constraints of mine operation, usually determine the most appropriate post-production land use.

In the case of open-pit or strip mining, the most expensive steps in the reclamation process are placing waste overburden at desirable slopes, backfilling the high walls, contouring, terracing, selective placement of overburden, and maintaining proper drainage patterns (Peterson and Etter, 1970). Therefore when these processes can be incorporated into the mining operation, considerable economic savings are possible in the post-extraction reclamation phase. The determination of the post-mining land uses will vary according to government requirements and with incentives in each province or territory.

In ascending order there are five broad levels of involvement to which land could be committed in the future (Riddle and Saperstein, 1978):

(i) Wilderness or unimproved use;

(ii) Forestry, limited agriculture, or outdoor recreation (e.g., grazing, hunting, fishing, logging);

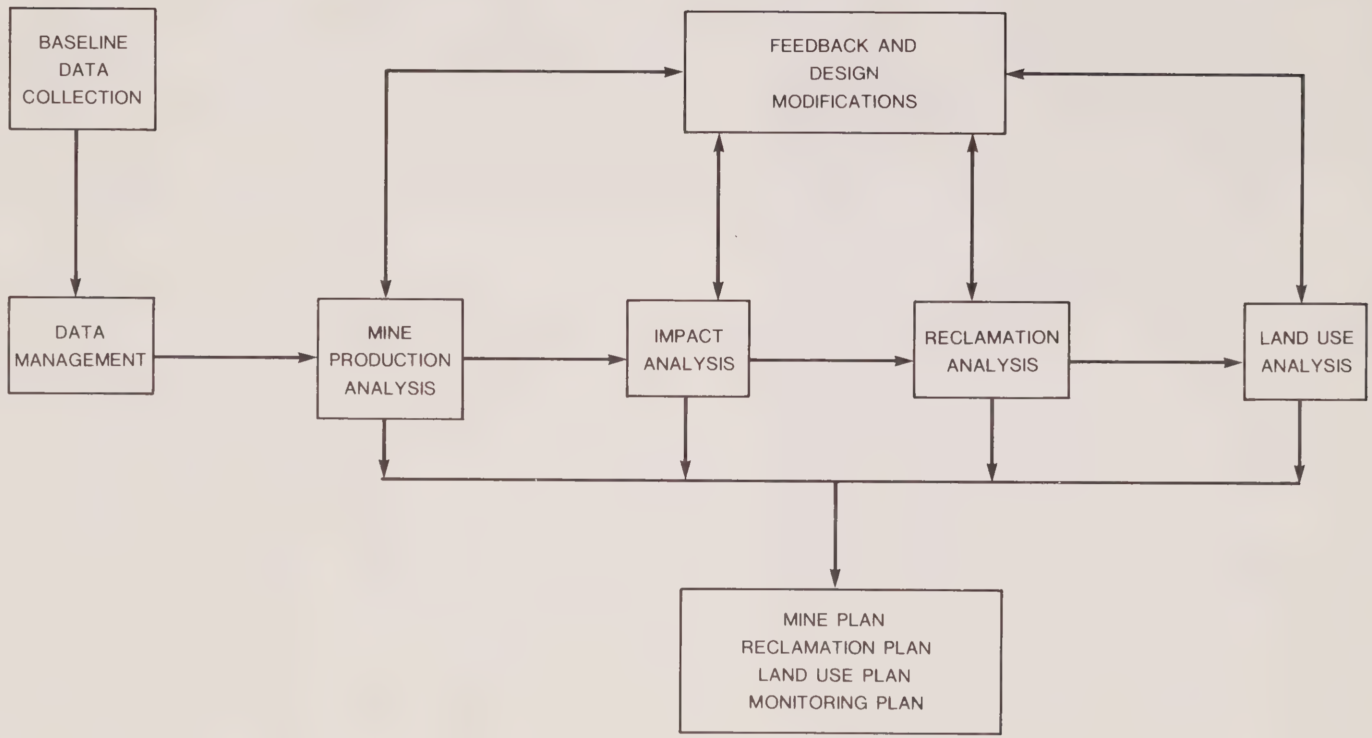
(iii) Agricultural and high-intensity recreation;

(iv) Suburban dwelling or light commercial; and

(v) High-density urban dwelling.

Most of the added costs and efforts are associated with the preparation of the land for new uses. Often new high-intensity uses ensure that a mining company's long-term responsibility is limited or completely terminated. From a practical viewpoint, however, the actual conceptual, spatial, and time aspects of the planning process defy definition because the long-term land use may ultimately develop in response to constantly changing conditions.

FIGURE 14. SCHEMATIC ILLUSTRATION OF PRE-PRODUCTION PLANNING PROCESS



The final reclamation plan chosen will be the result of weighing the constraints and finding an optimum balance between them. Usually this will require that some form of compromise is necessary because no two sites are the same, and technical limitations may be present which limit desired objectives. The functional requirements of a chosen land use will be a major factor in determining the design of the post-mining reclamation plan. For example, a coal mine located in the heart of the agriculturally dominated prairies would be required to return the land to some beneficial use based on economic returns, preferably agriculture. Under the circumstances, socio-economic attitudes, aesthetics and regulations demand , that the functional aspect becomes very important. In remote areas, on the other hand, the emphasis is less on putting land to some practical use than on ensuring that land is not left in such a condition as to cause any danger to, or degradation of, adjoining areas or to public health.

Therefore, economics, location, aesthetics, and land use play very important roles in determining the alternate function of an abandoned site, and the cost of potential conversion. More technical constraints on the ability to carry out reclamation are limitations imposed by materials found at the site, operational capabilities of machinery and equipment, and known reclamation techniques.

Site Preparation (landscaping)

Used in the broad sense of the word, this encompasses all the activities related to the removing of soils and overburden, disposal of wastes, and the modification of disturbed lands and disposal sites in order to facilitate reclamation of the mined areas. The process varies greatly from major earth moving and landscaping (backfilling, terracing, and contouring) to seedbed preparation (ripping, grading, ploughing, and harrowing) each for a specific purpose.

Site preparations include:

(i) Contouring slopes in backfilled pits and reshaping or terracing waste rock dumps (same procedures as indicated in extractive phase above;[8]

(ii) Reconstructing or diverting drainage channels;

(iii) Burying toxic wastes, or elimination of other physical inhibitors to plant growth;

(iv) Covering barren waste rock, tailings, or disturbed areas with previously stored topsoil, subsoil, or overburden. In many instances sufficient quantities of stockpiled material will not be available. Unless an alternate supply of material is available at low cost and without creating excessive disturbances elsewhere, extensive amelioration techniques will be necessary. If surface materials and soil amendments are used the costs increase considerably;

(v) Ripping the surface may be necessary due to compaction from large machinery used in backfilling and contouring. Ripping breaks up the surface and allows root penetration and improved water infiltration, reduces runoff; and aids in the integration of material cappings of topsoil or subsoils with underlying wastes, as well as preventing or reducing slippage and erosion;

(vi) Grading and levelling of topdressed areas in order to prevent excessive runoff and erosion (Hubbard and Bell, 1977); and

(vii) Seedbed preparation, including ploughing, discing, and harrowing.

In the total reclamation process, the various steps conducted in the site-preparation stage are the most costly and, therefore, it is advantageous to incorporate as many of them as possible into the operational extraction phase of mining, in order to reduce reclamation costs (Down and Stocks, 1977; Peterson and Etter, 1970).

Open-pit mines are usually associated with the stockpiling of the topsoil, subsoil, and overburden, and the backfilling of open pits with mine wastes. In the case of underground mines very little stockpiling and segregating topsoil and overburden takes place. In those situations, where it is not possible to place waste materials into open pits or valley depressions, the wastes are usually accumulated in piles, allowed to stand at the angle of repose of the coarser fraction, and adequate measures taken to divert natural drainage and prevent run off or seepage problems. The preparation of tailings has to wait until the final abandonment of the mine or until the containment area has reached its capacity. If above-grade disposal is practised, (as opposed to placing tailings in natural or artificial depressions) the susceptibility to wind erosion is more prevalent and measures such as wetting regularly, or sealing with chemical and physical stabilizers, must be taken to control dust.

In all cases, site preparation after the mining ceases involves improving the physical condition of the mined

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[8] Terrain or economic constraints often dictate that some "high walls" in the pits can be only partially covered, but that in many instances uncovered "high walls" may resemble normal cliffs sufficiently to preclude erosional problems or degradation of the aesthetic aspects of the reclaimed site.

Reclaimed coal mine overburden spoils, B.C. Coal Ltd., Sparwood, British Columbia
I.B. Marshall, Environment Canada

land, overburden, and waste disposal sites in preparation for revegetation. It is essential that soil analysis be conducted on all materials being reclaimed or used for fill and capping purposes especially where immense variation in the physical and chemical composition occurs both vertically and laterally.

Soil Amelioration

Soil amelioration is essential in order to overcome adverse conditions including salinity, pH, nutrient deficiencies, toxic compounds, poor texture and structure, or lack of organic matter. Normally, some soil amelioration is necessary on most mine wastes prior to any revegetation programs, particularly those of uranium and sulphide ores.

Site amelioration prior to, or in conjunction with, revegetation usually consists of:

(i) Further coverings of topsoil if necessary;
(ii) Seed bed preparation;
(iii) Surface treatments of mulches (straw, bark, brushwood), and/or adhesive chemical stabilizers (resinous adhesives, bitumen, polymers). Mulches and chemical methods are seldom permanent solutions, normally being most effective at preventing erosion and aiding the establishment of a vegetative cover; and
(iv) Soil amendments to neutralize acidity or make up nutrient deficiencies. Fertilizers are added in the early years and regularly for a number of years.

Revegetation

Principally revegetation is the process of establishing a vegetative cover on mineral wastes or mined areas so as to:

(i) Stabilize erodible slopes in order to minimize stream pollution;
(ii) Control dust;
(iii) Maximize aesthetic value;
(iv) Maximize evapotranspiration to minimize run off;
(v) Facilitate crop-production; and
(vi) Reduce oxidation — potential acid mine drainage (Williams, 1975).

It is the most physically and aesthetically effective method of stabilizing and rehabilitating mine wastes and disturbed sites.

There are two basic approaches to revegetation of mine wastes and disturbances (Down and Stocks, 1977). The first, is to accept adverse soil and site con-

ditions as they exist and choose plants which have a tolerance to the main environmental factors inhibiting plant growth (Goodman, 1974; Down and Stocks, 1977; Murray, 1977*b*). This has been referred to as the "ecological" approach emphasizing "native" or "volunteer" species.

The second approach is to improve the soil and site conditions to make them suitable for the growth of the particular species (often agronomic) required. In the case of the first approach, it must be recognized that there are some severe conditions under which no species could survive. If the second method can be used, more-rapid results as well as a wider choice of after use can be anticipated. In practice, a combination of the above approaches is widely adopted and successful (LeRoy and Keller, 1972; Hubbard and Bell, 1977; Murray, 1977*b*).

Where many environmental factors inhibit plant growth at a single site, revegetation becomes a complex task. In other situations, only a single site-specific problem may be the major factor limiting successful revegetation. Much can be done in site preparation through slope and drainage modifications and material capping.

Despite the wide variety of plant species available, their specific growth requirements usually narrow the choice considerably. Only those known to be adapted to disturbances within a given area or region should be used. Observation of natural plant succession and colonization on disturbances in the vicinity of the mine site help to determine adapted species. This is particularly true of plants at high elevations in the Foothills and Rockies in harsh northern climates, or those with a high tolerance to adverse salts, heavy metals, or toxic compounds.

Although many principles of agriculture and forestry have been applied to the revegetation of mined land, the methods and time of planting will differ, largely because the mine disturbances and wastes do not have a natural soil medium. Where reclamation is not geared to agriculture, it is aesthetically more pleasing that cluster or landscape planting be utilized to follow the topography rather than planting in rows. Similarly, planting to stabilize slopes and re-attract wildlife requires different approaches.

Grasses and legumes: Seeding of grasses and legumes is usually undertaken as soon as possible after mine wastes or disturbances have been dressed with topsoil, and just prior to the wettest time of year. Mechanical broadcasting, drill seeding, and hydroseeding methods are used in accordance with site-specific conditions. Drilling is the method by which the seeds are dropped from seeding machines into holes or furrows and then covered by earth. Drilling is usually the superior method of seeding where site conditions permit, but steep slopes and access are problems. On steep slopes (in excess of 3:1) broadcast seeding is more favourable (USDA, 1979). Broadcasting scatters the seed on the ground surface and the seeds may or may not be covered with earth. The method is less efficient than drilling because the seeds are often left exposed on the surface. Additional mechanical treatment is normally required to cover the seeds. Poor moisture conditions, soil texture, and compacted soils can further reduce its effectiveness. Other methods of broadcast seeding include hydroseeding, aerial seeding, and the use of hand-held cyclone seeders. Hydroseeders apply seed by means of high-pressure streams of water pumped from a truck-mounted tank containing water, seed, fertilizer, and possibly a mulching material. If a mulch is not applied at the hydroseeding stage, the seed has to be covered with soil or mulched in a separate operation to ensure germination. This method is used in rough terrain, along with aerial seeding, the latter being applied in areas of very limited access. Hand-held cyclone seeders are usually used to in-fill small areas or on experimental plots; their major restrictions are cost and slowness.

Trees and shrubs: Planting is almost exclusively done by hand or with the assistance of hand-held soil-displacement-type planters or engine-driven soil augers. Various sources are used, including container-grown plants, bare-root stock (grown in nursery beds for one to two years), cuttings (pieces of stems; usually from woody plants), wildings (individual plants transplanted from one natural ecological site to another), or plugs (fieldgrown, native clumps of vegetation dug up and replanted on another site). Large plugs or clumps of trees which may attract wildlife can be transplanted by using front-end loaders. The use of larger mature trees however, creates considerable problems of cost and maintenance. Many trees do not survive transplanting to different ecological settings and, hence, nursery stock needs to be obtained from the same ecological setting as the mine site, or have specially developed tolerance.

Revegetation practices differ from site to site with respect to the plant species, the soil amendments used, and the time required to achieve the desired cover. In many instances, the ultimate selection of the species used in revegetation at a given mine is based

upon fairly extensive trials in a test plot conducted during the pre-production or early production stages. Both seeding and planting techniques are utilized in many revegetation programs.

Physical and Chemical Stabilization

Mine wastes or disturbed lands can be stabilized as a substitute to revegetation to reduce blowing dust and water erosion. Chemical stabilization involves applying a chemical agent (resinous adhesives, bitumen, polymers, etc.) which bind the surface medium (soil, waste rock, tailings, etc.) to form an air- or water-resistent crust to stop erosion. The treated surfaces are seldom permanent, costs are high, and the results are not as aesthetically pleasing as revegetation. As indicated earlier, chemical methods are frequently employed along with revegetation techniques in order to protect seeds and young plants from erosion before they mature.

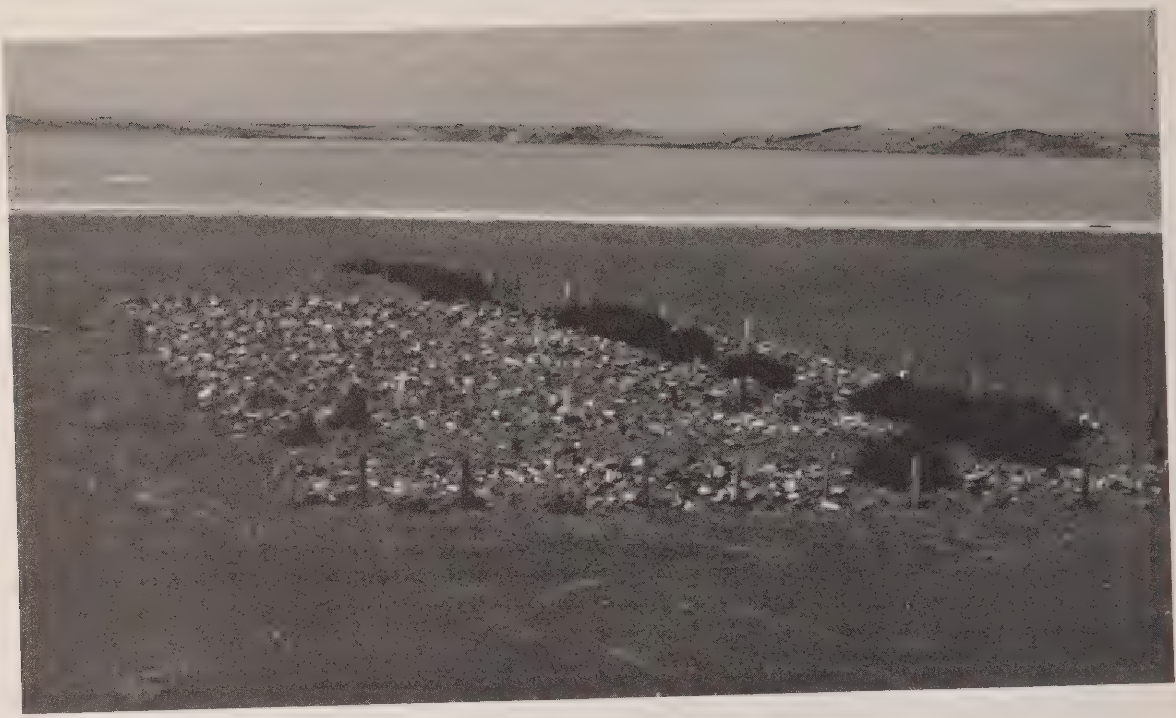
Physical stabilization methods are usually accomplished with the use of erosion-resistant waste rock, smelter slags, or stockpiled overburden. With the exception of the use of topsoil, most physical methods still leave an aesthetically unpleasing surface. However, physical methods may be used as an interior measure in the case of temporary closure to prevent erosion by air and water.

Follow-Up Maintenance and Monitoring

A management program of monitoring and maintenance is necessary to ensure that the goals of the reclamation or abandonment plan are met. The monitoring period is normally stipulated in regulations, and usually must be carried out over a specified time after final augmented seeding, refertilization, replanting, drainage changes, or other maintenance requirements. Some regulations may require that monitoring continue for several years to assess whether or not the operator has fulfilled his obligations to adequately reclaim the site, and in order to release reclamation funds or bonds posted with the government as security. Some areas will require a longer time if succession by native species is required in regulations of full restoration to pre-mining use (e.g. crop production). Monitoring also provides for revisions to reclamation plans where earlier work has proved inadequate. Many of the requirements for final mine abandonment are similar to those referred to earlier under "temporary closure".

The major concerns at this time are to ensure that the mechanisms, set in place to prevent the pollution of surface and subsurface water, are running efficiently. Final checks are made on water levels, fluctuations, quality and quantity of discharges or seepage if still present, and sampling above and below discharge or seepage points. This usually requires the maintenance of permanent impoundments, sediment basins, ditches, channels, and spillways, especially with respect to relocated streams.

Monitoring focuses on areas where revegetation has been less successful, where there are signs of erosion, siltation, or slope failures. Most problems are associated with south- and west-facing slopes, old access roads, former equipment or storage sites, high run-off sites, areas high in clay content, salts, heavy metals, or toxic compounds. Retreatment usually consists of chemical, physical, or biological improvements. Additional applications of fertilizer or lime are the most-common chemical treatments to assist the establishment of permanent vegetation (hence erosion protection) or to increase the build-up of the organic content of the soils. Physical treatments are normally associated with erosion, or slope failures. Maintenance can involve some earth moving, remulching, netting, fencing, or other stabilizing techniques. Biological changes or improvements include changes in seed mixtures or plant species, and replanting.



Revegetation test plots on active iron tailings, Hilton mine, Quebec
W.B. Blakeman, Environment Canada

Natural revegetation of abandoned lead tailings, Kingdom mine, Galetta, Ontario
W.B. Blakeman, Environment Canada

Chapter Three

DISTRIBUTION OF MINING

The distribution of mining is described in two ways: First, by province and territory; and secondly, a broad framework of "Land Resource Zones" allows mining to be discussed in relation to other land uses. This approach provides a basis for regional comparisons of mining activities within naturally recurring ecosystems, and of their potential effects on the environment.

General distribution patterns, data limitations, definitions of concepts, and the constituent elements of the land resource zones are outlined. There follows a more-detailed discussion of the principal commodities produced, distribution, value, reserves, and future development for metallic, non-metallic, and energy sectors of the industry.

MINERAL RESOURCES AND RESERVES

Mineral resources are referred to as all mineral deposits in the ground that are theoretically available within certain economic limits during a specific time span in the future (Dep. Energy, Mines and Resources, 1974). They include:

(i) Established reserves at all currently operating mines and known deposits committed for production.
(ii) Known but economically submarginal deposits (may include formerly producing mines).
(iii) Undiscovered mineral deposits in favorable geological formations.

In order to assess resources available on an annual basis, the Department of Energy, Mines and Resources (1979) divides estimates into five categories reflecting different levels of confidence in the quantities reported: Measured ore; Indicated ore; Inferred ore; Prognosticated resources; and Speculative resources (Figure 15).

Mineral reserves (measured and indicated ores) are defined as that portion of known mineral deposits which are reasonably well measured as to tonnage and grade, and could be mined profitably under current technological and economic conditions (Dep. Energy, Mines and Resources, 1974). Mineral reserves are a working inventory that is being replenished over time, and are not an expression of the ultimate supply of any mineral commodity. Reserves tend to change through increased or decreased production rates, additions of new discoveries, and reassessments resulting from changing economic conditions. The most significant changes in total reserves usually come from large new discoveries, others from improved mining and processing technology.

The other resource categories are not included because, at today's prices, it would not be profitable to mine them. However, as the relative price of a mineral goes up, the amount of proved reserves may increase, as with the oil sands in Alberta and gold deposits throughout Canada. Gold mines and placer diggings formerly believed to be worked out are now being reworked. In this review, the major focus of attention is on the measured, indicated, and inferred categories which are the most likely deposits to be developed within the next two decades.

GENERAL DISTRIBUTION PATTERNS

The distribution of mining regions and the principal commodities produced in Canada are shown on Map 1. The location and number of companies currently operating within each region under categories of metallic, non-metallic (industrial minerals), coal, and oil sands are shown on Map 2. Not all mine sites are marked so the actual number of individual mines operating within a given area is greater in some cases. As of January, 1979, the 203 operating companies (*see* Map 2), represented a total of 282 mine sites and 230 mills (excluding placer, lime, cement, and oil sands operations). This represents a reduction from 320 mines in 1977. The location of smelters and refineries are identified on Map 3.

Maintenance of an accurate overview of all currently operating mine and milling operations of companies is extremely difficult due to rapid changes in the quality of ore bodies, technology, and changing market conditions. Mines may close and re-open several times over short periods of time. Also, the distribution of operating companies cannot be used as a true measure of

Hudson Bay Mining and Smelting underground gold and silver mine, Osborne Lake, Manitoba
NFB — Phototheque — ONF, Bryce Flynn

MAP 1. - Key to Principal Mining Regions of Canada

NEWFOUNDLAND

1. Avalon Peninsula	Pyrophylite
2. St. Lawrence	Silica
3. Buchans	Zn, Pb, Cu, Ag, Au, Cd.
4. Springdale-Baie Verte	Cu, Au, Ag, Asbestos
5. Stephenville	Gypsum

NOVA SCOTIA

6. Sydney-Cape Breton	Coal, Gypsum
7. New Glasgow	Coal
8. Wolfville - Stewracke	Gypsum, Pb, Zn, U
9. Moncton - Springhill	Coal, Salt, Gypsum

NEW BRUNSWICK

10. Minto	Coal, Potash
11. Fredericton	Sb
12. Bathurst	Pb, Zn, Cu

QUEBEC

13. Quebec - Labrador	Fe
14. Havre St. Pierre	Fe, Ti
15. Gaspé	Cu, Mo
16. Baie St. Paul	Fe
17. Eastern Townships	Asbestos, Talc, Soapstone
18. Montreal	Silica, Magnesite, Magnesitic dolomite
19. Ottawa Valley	Mg, Ca
20. Maniwaki	Ni, Cu, Fe
21. Belleterre	Ni, Cu
22. Noranda - Val d'Or	Cu, Zn, Ag, Au, Pb
23. Matagami	Zn, Cu
24. Chibougamau	Cu, Au, Ag
25. Putuniq - Hudson Strait	Asbestos

ONTARIO

26. Bancroft - Marmora	Talc, Nephaline Seyenite, Dolomite, U
27. Hagersville	Gypsum
28. Windsor	Salt
29. Sarnia	Salt
30. Goderich	Salt
31. Elliot Lake	U
32. Sudbury Basin	Ni, Cu, Au, Ag, Platinum Metals, Co, Se, Te, Fe, U,
33. Kirkland Lake - Cobalt	Au, Ag, Fe
34. Timmins - Porcupine	Zn, Cu, Au, Ag, Pb, Sn, Cd
35. Algoma	Fe
36. Long Lac	Cu, Zn, Ag, Pb
37. Steep Lake	Fe, Ni, Cu
38. Pickle Crow	Cu, Ni, Ag
39. Red Lake	Au, Cu, Zn, Ag, Fe

MANITOBA

40. Bissett-Black Island	Silica
41. Morris-Morden	Bentonite
42. Neepawa	Gypsum
43. Gypsumville	Gypsum
44. Flin Flon-Snow Lake	Cu, Zn, Au, Ag, Pb, Cd, Se, Te
45. Thompson	Ni, Cu, Co, Precious Metal Residues
46. Lynn Lake	Cu, Zn, Ag
47. Lac du Bonnet	Ta, Ce

SASKATCHEWAN

48. Estevan - Bienfait	Coal
49. Regina - Moose Jaw	Sodium Sulphate, Potash, Salt, Bentonite
50. Saskatoon	Potash, Sodium Sulphate, Salt
51. La Ronge	Cu, Ni, Zn, Pb
52. Key Lake	U
53. Cluff Lake	U
54. Athabasca Sandstone - Rabbit Lake	U
55. Uranium City	U
56. Esterhazy	Potash

ALBERTA

57. Grande Cache	Coal
58. Luscar	Coal
59. Edmonton	Coal, Barite, Silica
60. Forestburg	Coal, Bentonite
61. Drumheller	Coal
62. Lethbridge	Coal
63. Canmore	Coal
64. Lindbergh	Salt
65. Metiskow	Sodium Sulphate

BRITISH COLUMBIA

66. Invermere	Barite, Gypsum
67. Kimberley	Pb, Zn, Ag, Sb, Cd, Bi, Sn, In
68. Coleman - Crow's Nest	Coal
69. Revelstoke	Ag, Zn, Pb
70. Trail - Princeton	Cu, Mo, Ag, Au, Pb, Zn
71. Highland Valley	Cu, Mo, Ag, Au
72. Hope	Cu, Au, Ag
73. Vancouver Island	Cu, Mo, Au, Ag, Pb, Zn, Re
74. River Jordan	Cu
75. Britannia Beach	Au, Ag, Pb, Zn, Cd
76. Birch Island	U
77. Caribou	Cu, Mo, Ag
78. Central B.C.	Cu, Au, Ag, Mo
79. Queen Charlotte Is.	Fe, Cu, Ag
80. Stewart	Cu
81. Peace River	Coal
82. Cassiar	Asbestos
83. Fort Nelson	Cu, Pb, Zn

YUKON TERRITORY

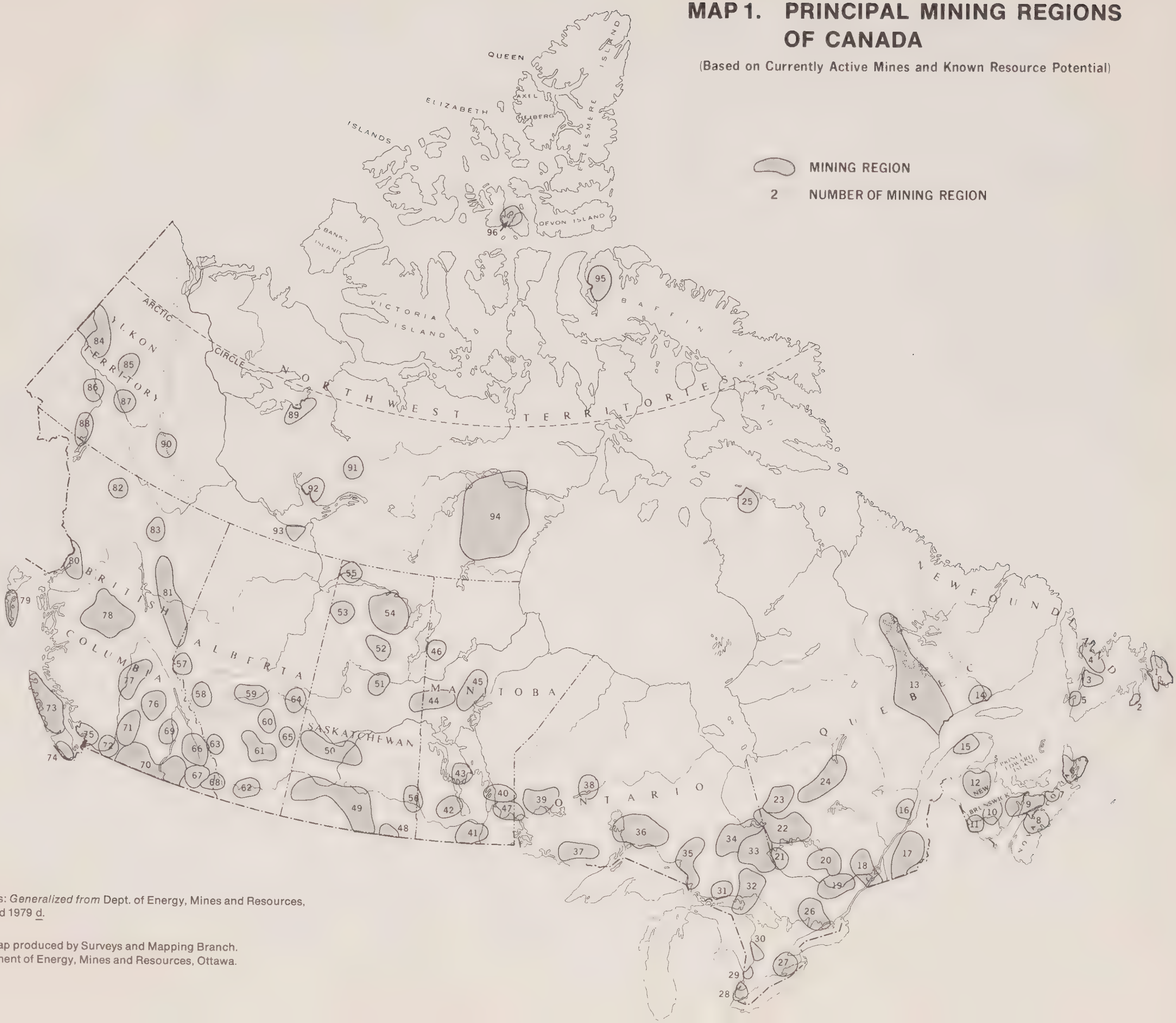
84. Clinton Creek	Asbestos
85. Mayo	Ag, Pb, Zn, Cd
86. Carmacks	Coal
87. Faro	Pb, Zn, Ag, Cu, Cd
88. Whitehorse-Carcross	Cu, Au, Ag

NORTHWEST TERRITORIES

89. Great Bear Lake	Ag, Cu
90. Tungsten	W, Cu
91. Mackay Lake	Au, Base Metals
92. Yellowknife	Au,
93. Pine Point	Zn, Pb
94. Baker Lake	U
95. Arctic Bay	Pb, Zn, Ag,
96. Little Cornwallis Island	Zn, Pb

MAP 1. PRINCIPAL MINING REGIONS OF CANADA

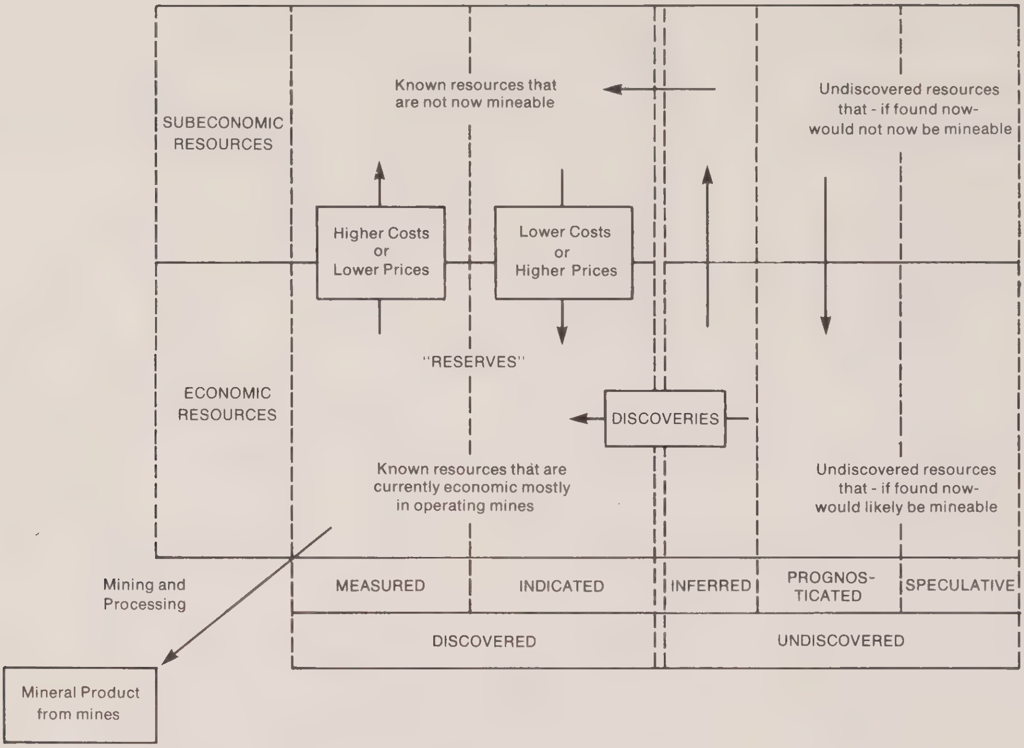
(Based on Currently Active Mines and Known Resource Potential)



Sources: *Generalized from* Dept. of Energy, Mines and Resources, 1975 and 1979 d.

Base map produced by Surveys and Mapping Branch. Department of Energy, Mines and Resources, Ottawa.

FIGURE 15. CLASSIFICATION AND FLOW OF MINERAL RESOURCES OVER TIME



DEFINITIONS OF RESOURCES: Measured ore refers to ore for which tonnage is computed from dimensions revealed in outcrops, trenches, working, or drillholes, and for which grade is computed from adequate sampling. The sites for inspection, sampling, and measurement are so closely spaced and the geological character is so well defined that the size, shape and mineral content are well established. The tonnage and grade should refer to ore recoverable by mining with due regard for dilution.

Indicated ore refers to ore which tonnage and grade are computed partly from specific measurements, samples or production data and partly from projection for a reasonable distance on geological evidence. The openings or exposures available for inspection, measurement and sampling are too widely or inappropriately spaced to outline the ore completely or to establish its grade throughout.

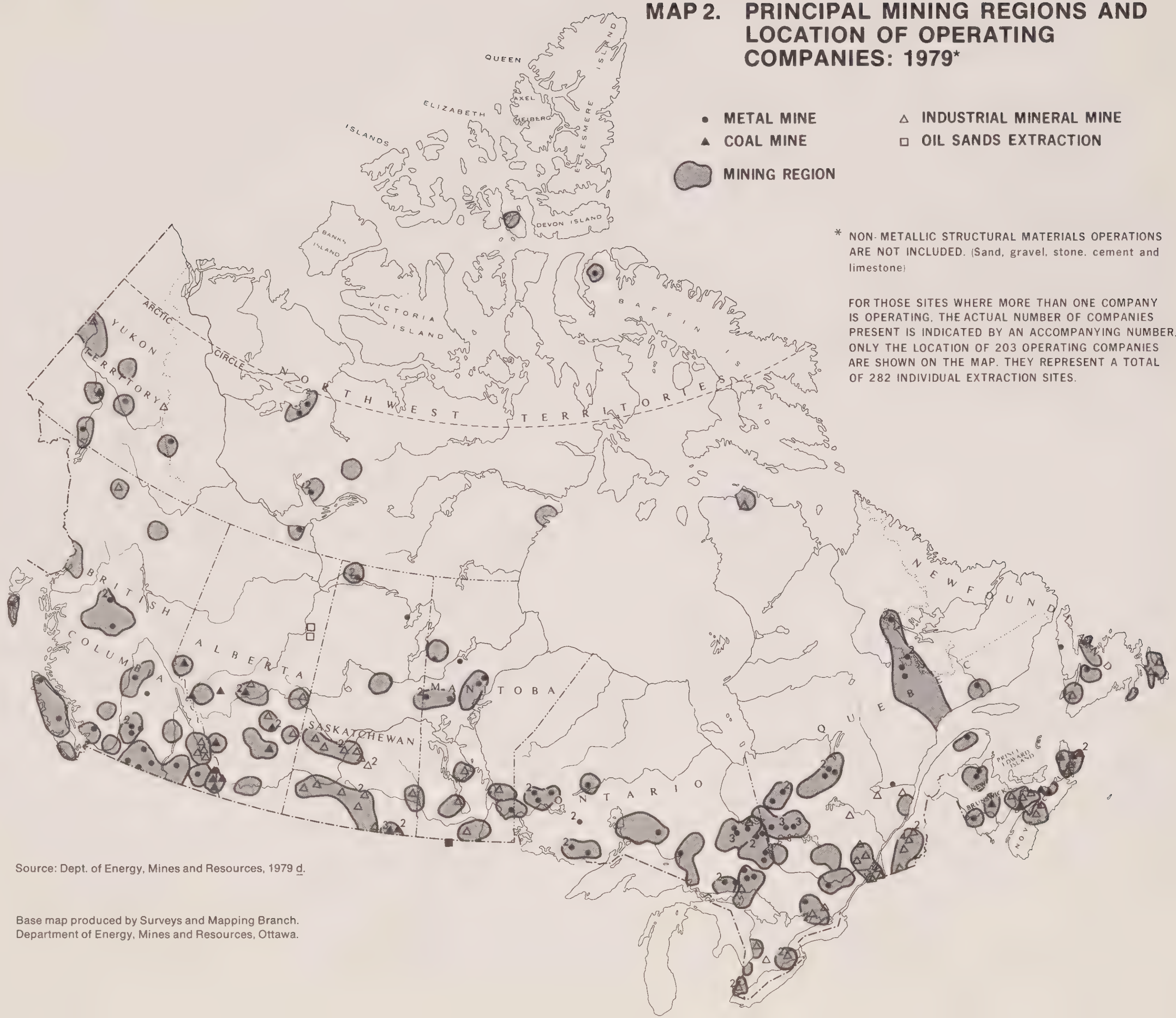
Inferred ore refers to ore for which quantitative estimates are based largely on broad knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements. Estimates are based on assumed continuity or repetition for which there is geological evidence; this evidence may include comparison with deposits of similar types. Bodies that are completely concealed but for which there is some geological evidence may be included. Estimates of inferred material may lie. These limits vary depending upon the characteristics and knowledge of the orebodies.

Prognosticated resources refer to estimated tonnages beyond specific limits established for inferred ore. They may include tonnages of portions of identified orebodies or of concealed satellite orebodies, the existence of which can be assumed along well established geological trends associated with known deposits. The attributes of prognosticated resources are, as a rule, derived by extrapolation identified deposits or by quantification of geological information.

Speculative resources refer to estimated tonnages in deposits thought to exist on the basis of indirect indications and geological extrapolations in virgin areas or in areas where only occurences are known.

Source: Whillans and Cranstone, 1979; and Dep. Energy, Mines and Resources, 1979 c

MAP 2. PRINCIPAL MINING REGIONS AND LOCATION OF OPERATING COMPANIES: 1979*



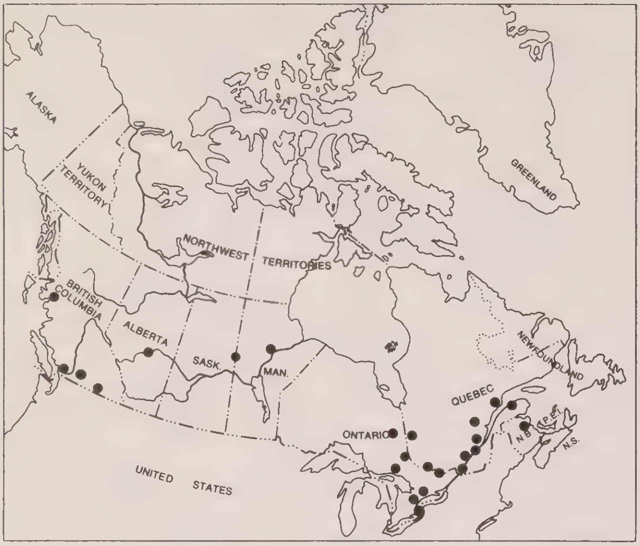
* NON-METALLIC STRUCTURAL MATERIALS OPERATIONS ARE NOT INCLUDED. (Sand, gravel, stone, cement and limestone)

FOR THOSE SITES WHERE MORE THAN ONE COMPANY IS OPERATING, THE ACTUAL NUMBER OF COMPANIES PRESENT IS INDICATED BY AN ACCOMPANYING NUMBER. ONLY THE LOCATION OF 203 OPERATING COMPANIES ARE SHOWN ON THE MAP. THEY REPRESENT A TOTAL OF 282 INDIVIDUAL EXTRACTION SITES.

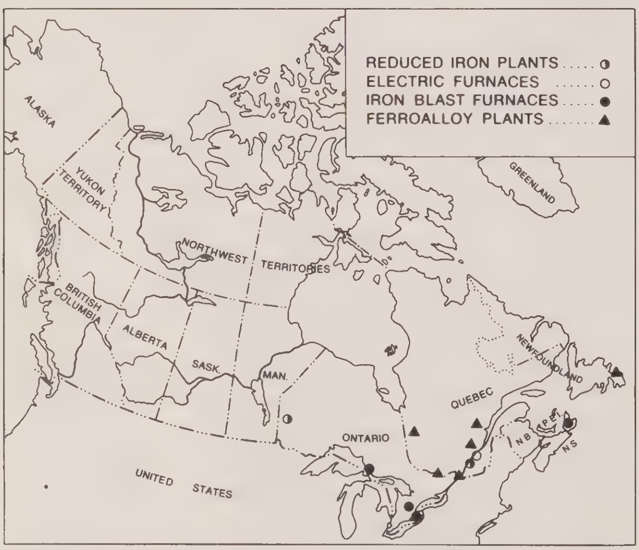
Source: Dept. of Energy, Mines and Resources, 1979 d.

Base map produced by Surveys and Mapping Branch. Department of Energy, Mines and Resources, Ottawa.

MAP 3. NONFERROUS SMELTERS AND REFINERIES; PIG IRON, REDUCED IRON, AND FERROALLY PLANT SITES



3a NONFERROUS SMELTERS AND REFINERIES



3b PIG IRON, REDUCED IRON AND FERROALLOY PLANTS

Reproduced from: Dept. of Energy, Mines and Resources, 1979 d.

the number and distribution of individual mines, production status, or extent of land requirements for all stages of mineral production.

Mines are not all fully integrated operations and, as such, their land requirements vary considerably. This diversity can be illustrated by reference to specific cases within identified mineral producing areas.

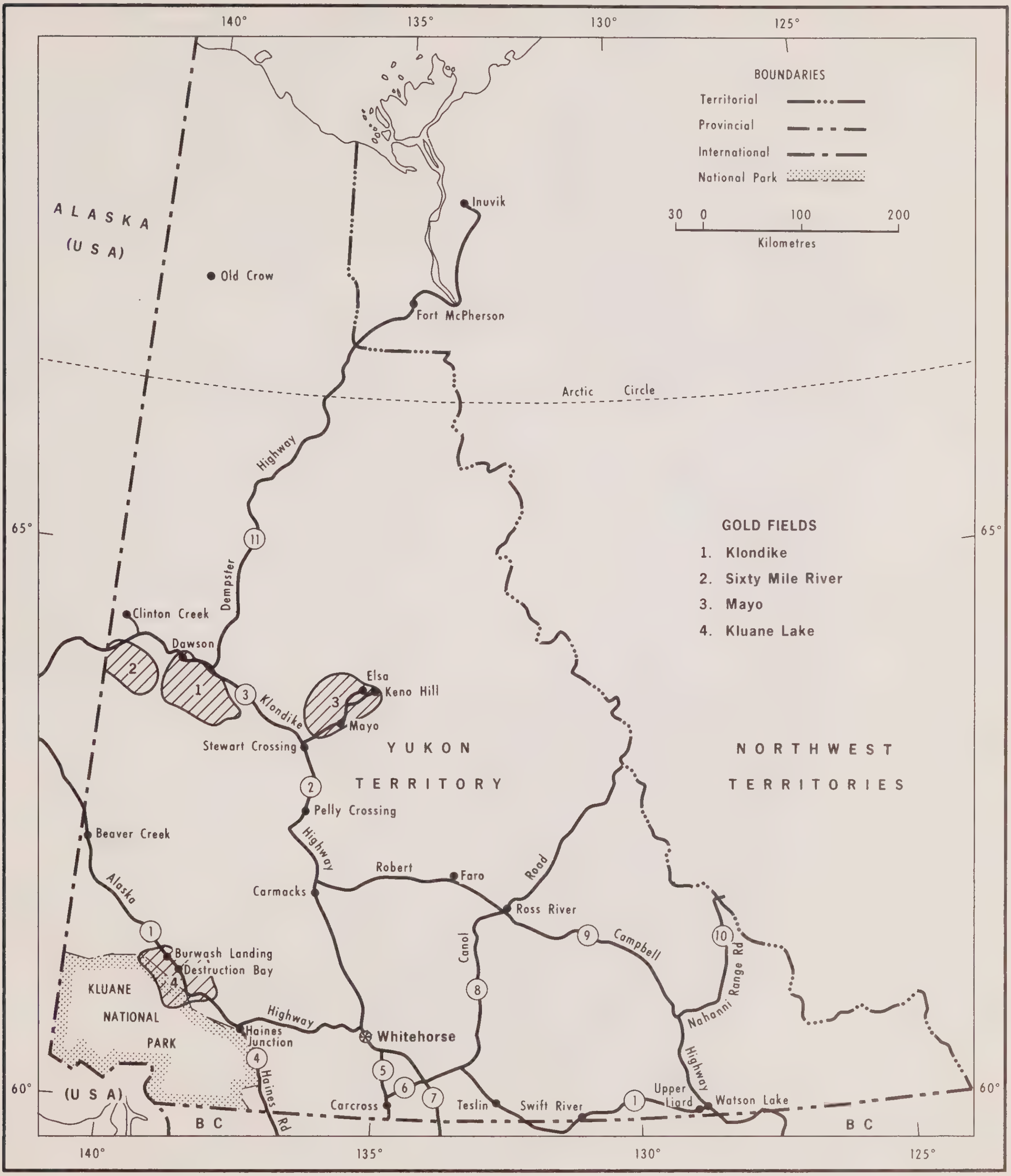
(i) Chibougamau Region, Quebec (*see* Map 1, no. 24). In this region, Campbell Chibougamau Mines Ltd. operated four individual copper mines (Orignal, Grandroy, Cedar Bay, and Henderson Mines). In May, 1975, all mine operations were suspended, by September the Cedar Bay mine resumed operation, and in May, 1976 the Henderson mine. The other two mines remained on a stand-by basis. However, the milling rate remained at approximately 30 percent of capacity. In the same region, operations at three of four underground mines owned by Patino Mines Que. Ltd. were suspended.

(ii) Sudbury Region, Ontario (*see* Map 1, no. 32). In the Sudbury Basin, two companies, INCO and Falconbridge Nickel Mines, between them operate 21 underground mines and two open pits, of which four underground mines were closed and one re-opened in 1977. In the case of Falconbridge, six (operating) mines have their ore milled at the Strathcona and Falconbridge Mills. Three mills, Clarabelle, Frood-stobie, and Levack, beneficiate ores mined by INCO's 13 operating mines.

(iii) Flin Flon — Snowlake Region (*see* Map 1, no. 44). Ore from seven underground mines of Hudson Bay Mining and Smelting Co. in this region are treated at the Flin Flon Mill. Copper concentrate is reduced to copper anodes at the the Company's smelter and refined at Canadian Copper Refiners Ltd., Montréal. Zinc concentrate is smelted and refined locally, but lead concentrate is shipped to Cominco Ltd. in Trail, British Columbia. By-product elements of the refining processes are gold, silver, cadmium, selenium, and tellurium.

Significant omissions from the distribution maps are the locations for construction materials (predominantly sand, gravel, and crushed stone) which number in the thousands and are scattered widely in sizes ranging from less than a hectare to over 100 hectares. Cartographically, this would be beyond the scope of this study, and accurate locational records of all operations are not available on a nation-wide basis. Similarly in

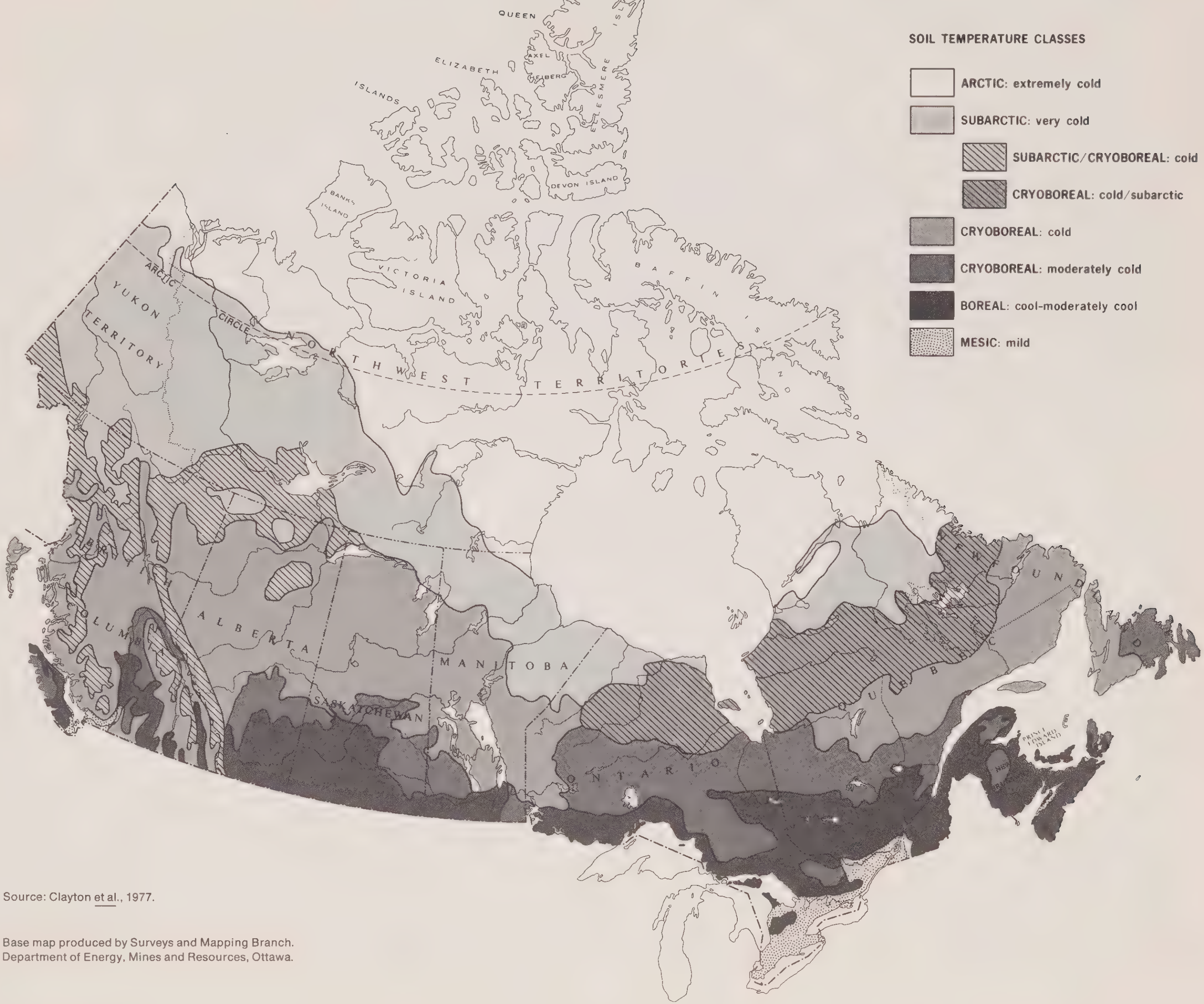
MAP 4. ACTIVE PLACER GOLD FIELDS IN THE YUKON TERRITORY



MAP 5. KEY TO SOIL TEMPERATURE CLASSES

Soil Temperature Classes and Subclasses	Description	Mean Annual Soil Temp. (°C)	Description of Summer (°C)	Mean Summer Soil Temp. (°C)	Growing Season	Soil Temperatures Days Over		Degree Days Over	
						5°C	15°C	5°C	15°C
1. Arctic	Extremely cold	< -7°	Cold to very cool	<5°	Nearly none	<15	None	None	
2. Subarctic	Very cold	-7° to<2°	Moderately cool	5° to 8°	Short	<120	None	<1000	
3. Cryoboreal	Cold to moderately cold	2° to 8°	Mild	8° to 15°	Moderately short to moderately long	120-220	< 60	1000-2250	
Cold Cryoboreal					Moderately short		None	1000-2000	
Moderately Cold Cryoboreal					Moderately short to moderately long		Short period only	2000-2250	
4. Boreal	Cool to moderately cool	5° to 8°	Mild to moderately warm	15° to 18°	Moderately short to moderately long	170-220	>60	2250-3000	60-400
Cool Boreal					Moderately long		very short to short	2250-2500	
Moderately Cool Boreal					Moderately long		short	2500-3000	
5. Mesic	Mild to moderately warm	8° to 15°	Moderately warm to warm	15° to 22°	Moderately long to nearly continuous	200-365	<180	3100-5000	300 1200
Mild Mesic					Moderately long		short period	3100-4000	

MAP 5. SOIL CLIMATIC CONDITIONS



Source: Clayton et al., 1977.

Base map produced by Surveys and Mapping Branch.
Department of Energy, Mines and Resources, Ottawa.

the Yukon, where thousands of placer mining claims and leases have been issued in the past few years with the dramatic increase in gold prices, their locations have been confined to pinpointing the four active gold fields (Map 4).

Data on new mine developments, reopenings, and expansions are relatively firm in that commitments have been made for production within the period 1979 to 1985. Even these commitments, however, are never free of changing political, economic, or environmental conditions that could delay or even cancel them. In the case of mineral deposits known to be promising for future production, consideration has to be given to:

". . .qualitative information of such factors as probable mining method, metallurgical characteristics, accessibility, favourability of terrain, existence of a nearby community, availability of transportation, power, communications, and labour force.

Many of the deposits may now be economic, but the development of such deposits may have been delayed for various reasons. For instance, an owner's investment priorities may be such that he prefers to keep a given deposit "on the shelf", or a company may be unable to raise the capital required for development of an apparently economic deposit. In many cases, corporate reasons for delay in development are not immediately evident." (Whillans and Cranstone, 1979).

In addition, the geographic distribution of mineral activities has been strongly dependant on developments in transportation. Although aircraft and helicopters have allowed widespread exploration in northern frontier regions, the actual development of new mines in the largely unexplored and generally inaccessible areas will require new developments in transportation. If extensive support facilities, such as transport corridors are needed, much larger areas will be affected.

LAND RESOURCE ZONES

The "Land Resource Zones" established for this study are based on seven physiographic regions established previously for Canada: Appalachian, St. Lawrence Lowland, Shield, Hudson Bay Lowland, Interior Plains, Cordilleran, and Arctic Archipelago (Bostock, 1970). These regions dictate the type of land available through relief, soils, and mineral content. A combination of soil climatic conditions (Map 5) and forest zones (Map 6) have been used to separate further the seven physiographic regions into the final twelve Land Resource Zones, referred to hereafter as LRZ numbers (Map 7). Table 11 provides a summary of the most significant land uses and resource developments within each Land Resource Zone. A general description of physiographic features, vegetation, soil climates, land use, and major mining commodities produced for each zone can be found in Appendix V.

Throughout this chapter maps with the Land Resource Zone framework are used to summarize data on existing and future mining in order to focus on those zones in which mining activities continue to play an important role and to identify those mineral sectors which are receiving increased attention, through exploration and/or proposals for new development.

CURRENT PRODUCTION AND DISTRIBUTION

METALLIC MINERALS

Metallic minerals (*see* Table 1) are mined in all provinces and territories with the exception of Prince Edward Island (*see* Map 2) and account for 60 percent of all mining revenues (excluding oil-sands extraction). The quantity and value of each mineral produced in 1979 and 1980 are presented in Table 12. The principal non-ferrous (copper, nickel, lead, zinc, and molybdenum) and precious metals (gold and silver) account for almost 70 percent of the total value of metallic ores produced. Currently, those seven metals are produced from more than 125 mines. These are operated by some 55 mining companies, about one-half of which account for 90 percent of the total production of each metal (Dep. Energy, Mines and Resources, 1980*b*). The value of iron ore and uranium ore production is 17 and 6 percent respectively of the total.

Ferrous Metals

Of the ***iron ore*** mined in Ontario, Quebec, Newfoundland (Labrador), and British Columbia, more than 75 percent is mined in the Quebec-Labrador border area (Map 8b). Three types of iron ore are mined, namely hematite (81 percent), magnetite (17 percent), and siderite (2 percent). All but two percent of the hematite is mined in the Quebec-Labrador region (*see* Map 1, no. 13). All the magnetite is mined in Ontario. The only mine using siderite ore is the Algoma Steel Corp. Ltd. at Wawa, Ontario. A small amount of pyrrhotite (iron sulphide) is produced as a by-product of nickel production at Inco Ltd., Sudbury.

All the iron mines use open-pit operations with the exception of two (Algoma Steel Corp. Ltd., Ontario

Sources: Canadian Forestry Service, 1979 and Clayton et al., 197

Base map produced by Surveys and Mapping Branch.
Department of Energy, Mines and Resources, Ottawa.

TABLE 11. LAND-RESOURCE ZONES AND LAND USES

LAND RESOURCE ZONES \ LAND USE ACTIVITIES		Agriculture - Field Crops and Grazing	- Ranching and Grazing	- Horticultural	- Mixed Farming and Forage	Forestry	Fisheries	Urban Settlement	Oil and Gas	Wildlife - Wilderness Preservation	Hunting and Trapping	Tourism - Scenic	Outdoor Recreation	Native Peoples (Rights/Claims)	Mining - Metallic	- Non-metallic Industrial	- Non-metallic Structural	- Coal	- Oil Sands
I.1	Northern Cordilleran						X			XX	XX	X		XX					
I.2	Southern Cordilleran		XX	XX	X	XX	XX	X		XX	X	XX	XX	XX				XX	
II.1	Northern Interior Plains						X		XX	X	XX			XX			X		
II.2	Central Interior Plains (Peace, Athabasca)	XX			X	X	X		XX	X	X	X	XX	X				X	XX
II.3	Southern Interior Plains (Prairies)	XX	XX					X	XX							XX	X	XX	
III.	Arctic Archipelago									XX				XX			X		
IV.1	Southern Boreal Shield				X	XX	XX			X	XX	XX	XX	X	XX	X			
IV.2	Central Subarctic Shield					X	XX			XX	XX			XX	XX				
IV.3	Arctic Shield									XX	XX			XX					
V.	Hudson Bay Lowland									X									
VI.1	Lower Great Lakes			XX	XX			XX				XX	XX			X	XX		
VI.2	Central St. Lawrence Lowlands			XX	XX			XX				XX	XX				XX		
VII.	Appalachian			X	XX	XX	XX	X		X	X	XX	XX		X	XX	X	XX	

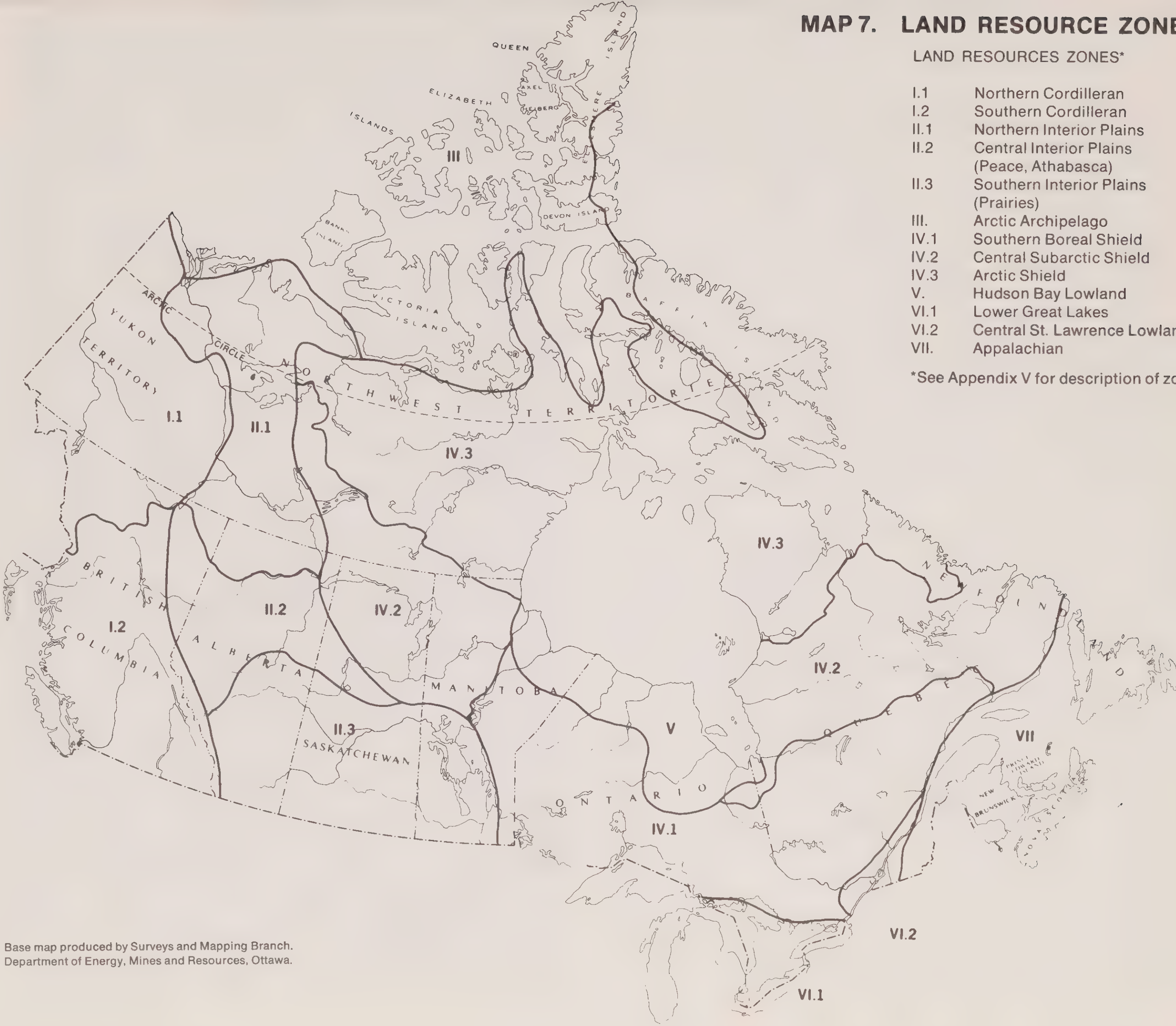
X - Significant XX - Major

MAP 7. LAND RESOURCE ZONES

LAND RESOURCES ZONES*

I.1	Northern Cordilleran
I.2	Southern Cordilleran
II.1	Northern Interior Plains
II.2	Central Interior Plains (Peace, Athabasca)
II.3	Southern Interior Plains (Prairies)
III.	Arctic Archipelago
IV.1	Southern Boreal Shield
IV.2	Central Subarctic Shield
IV.3	Arctic Shield
V.	Hudson Bay Lowland
VI.1	Lower Great Lakes
VI.2	Central St. Lawrence Lowlands
VII.	Appalachian

*See Appendix V for description of zones.



Base map produced by Surveys and Mapping Branch.
Department of Energy, Mines and Resources, Ottawa.

and Westrob Mines Ltd., B.C.) which use a combination of open-pit and underground methods. However, underground methods at the two mines accounted for less than three percent of the iron ore mined in Canada. In the period between 1977 and the end of 1979, six iron mines closed, four in Ontario and one each in Quebec and British Columbia. It is expected that more requirements for domestic and export needs can be met beyond the year 2000 from currently operating mines and from known but undeveloped mineral deposits considered likely to be brought into production (Dep. Energy, Mines and Resources, 1975).

Non-Ferrous Metals

The production of ***nickel*** and ***molybdenum*** ores are more geographically concentrated than iron ore operations (*see* Maps 8b and 8c). Almost 98 percent of the molybdenum is mined in British Columbia, whereas Ontario produces 75 percent of the nickel and Manitoba the remainder. However, this is not the case for copper, lead and of zinc, which are mined in all provinces and territories, except Prince Edward Island, Nova Scotia, and Alberta (*see* Map 8c). In terms of production, the leading lead/zinc producers in 1979 were New Brunswick (24/23 percent), Yukon Territory (26/10 percent), and the Northwest Territories (17/18.5 percent).

British Columbia produces 44.5 percent of Canada's ***copper*** and 28 percent of its ***lead***, followed by Ontario with 29 percent of copper and 24 percent of zinc production. Most of Canada's molybdenum is produced as a by-product of copper refining, with the exception of a single mine in British Columbia.

Throughout Canada copper, nickel, lead, zinc, and molybdenum ores are usually mined by underground methods. There are, however, an increasing number of instances in which ore bodies are sufficiently near the surface to permit open-pit mining throughout the entire life of the mine. These operations have become more common in British Columbia (12 mines in 1979), particularly with copper, copper/molybdenum, molybdenum, and lead/zinc ores. However, there are eleven other open-pit and open-pit/underground complexes scattered across Canada.

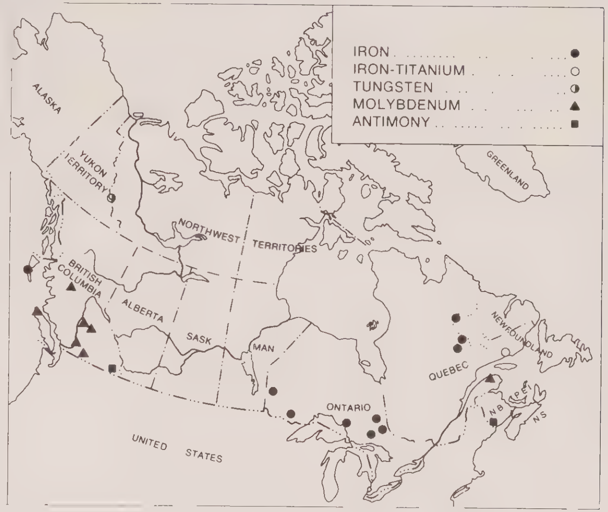
The mineral area planning study forecast that:

(i) "All nickel ore requirements for expected domestic and export needs can be met into the next century from operating mines and from known but undeveloped mineral

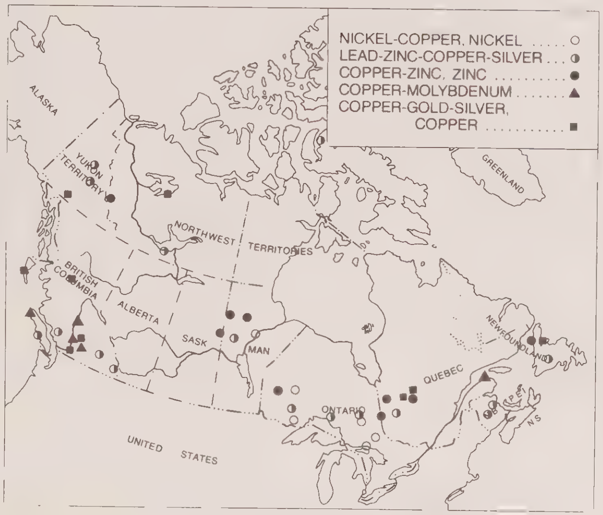
Iron Ore Company of Canada's rail and harbour facilities at Sept-Iles, Quebec
NFB — Phototheque — ONF, George Hunter

MAP 8. METALLIC AND NON-METALLIC PRODUCING AREAS: 1979

8a



8b



8c

8d

Reproduced from: Dept. of Energy, Mines and Resources, 1979 d.

TABLE 12. PRODUCTION IN CANADA BY QUANTITY AND VALUE OF PRODUCT
1979, 1980

METALS	Unit of Measure	Quantity		$ Value	
		1979	1980	1979	1980
		'000	'000	'000	'000
Antimony	kg	-	-	8,350	6,503
Bismuth	kg	137	171	974	1,269
Cadmium	kg	1,209	1,053	8,620	7,790
Calcium	kg	456	525	2,152	3,033
Cobalt	kg	1,640	1,603	109,344	95,019
Columbium	kg	2,513	2,330	15,292	15,005
Copper	kg	636,383	708,416	1,511,200	1,856,031
Gold	g	51,142	48,284	590,766	1,020,151
Indium	g		-	-	-
Iron Ore	t	59,617	50,866	1,807,399	1,722,812
Iron, Remelt	t	-	-	61,067	125,912
Lead	kg	310,745	273,833	410,518	299,134
Magnesium	kg	9,015	8,899	24,444	27,037
Molybdenum	kg	11,175	12,198	332,024	315,423
Nickel	kg	126,482	194,947	828,617	1,678,607
Platinum	g	6,157	12,584	58,334	155,480
Selenium	kg	218	246	6,908	11,296
Silver	kg	1,147	1,037	478,399	817,961
Tantalum	kg	159	127	14,521	22,500
Tellurium	kg	42	45	2,192	1,240
Tin	kg	337	264	5,565	5,898
Tungsten	kg	3,254	4,650	-	-
Uranium	kg	6,530	6,368	616,168	637,717
Zinc	kg	1,099,926	894,575	1,060,103	859,880
Total Metals				$7,952,957	$9,685,698

STRUCTURAL MATERIALS	Unit of Measure	Quantity		$ Value	
		1979	1980	1979	1980
		'000	'000	'000	'000
Clay Products		n.a.	n.a.	121,526	114,266
Cement	t	11,765	10,497	653,877	657,402
Lime	t	1,859	2,063	82,774	102,810
Sand and gravel	t	285,221	327,860	457,120	511,582
Stone	t	109,719	103,281	330,708	339,438
Total Structural Material				$1,646,005	$1,725,498

Source: Statistics Canada, 1978, 1979, 1980.

TABLE 12. PRODUCTION IN CANADA BY QUANTITY AND VALUE OF PRODUCT
1979 , 1980

NON-METALS	Unit of Measure	Quantity 1979 '000	Quantity 1980 '000	$ Value 1979 '000	$ Value 1980 '000
Asbestos	t	1,493	1,335	607,461	641,737
Barite	t	-	-	1,953	2,562
Gemstones	kg	-	-	1,391	1,470
Gypsum	t	8,098	7,209	41,126	43,670
Magnesite dolomite and brucite	t	-	-	8,990	10,405
Nepheline syenite	t	606	592	15,180	15,877
Peat	t	480	488	41,150	42,506
Potash	t	7,074	7,532	735,247	986,220
Pyrite Pyrrhotite	t	31	32	275	345
Quartz	t	2,368	2,624	26,579	29,318
Salt	t	6,881	7,029	109,848	125,845
Soapstone, talc	t	90	87	3,439	3,086
Sodium sulphate	t	443	496	25,211	28,930
Sulphur in smelter gas	t	667	903	14,515	22,955
Sulphur, elemental	t	6,314	7,403	159,642	414,484
Titanium dioxide	t	-	-	75,670	110,559
Total Non-Metals				$1,867,677	$2,479,969

FUELS	Unit of Measure	Quantity 1979 '000	Quantity 1980 '000	$ Value 1979 '000	$ Value 1980 '000
Coal	t	33,200	36,500	860,000	946,000
Natural Gas	m^3	94,426	84,402	4,855,845	6,692,200
Natural gas by-products	m^3	19,664	18,738	1,449,015	1,741,474
Petroleum Crude	m^3	86,910	84,198	7,451,855	9,098,104
Total Fuels				$14,616,715	$18,477,778

Source: Statistics Canada, 1978, 1979, 1980.

deposits considered likely to be brought into production.

(ii) "Copper, lead, molybdenum, and zinc requirements for expected domestic and export needs can essentially be met until the middle or late 1980's from operating mines and from known but undeveloped mineral deposits considered likely to be brought into production; thereafter, to meet the forecast requirements, production will need to be supplemented from other known mineral deposits or from deposits yet to be discovered." (Dep. Energy, Mines and Resources, 1975).

The polymetallic nature of many non-ferrous ores containing copper, lead, zinc, nickel, or molybdenum usually results in a mine producing significant tonnages of a co-product or by-product (*see* Table 1). The most significant of these associated with the above five metals are gold and silver (*see* Map 8c). Selenium, tellurium, and bismuth are produced at mines in the Sudbury and Flin Flon regions and at Murdochville in the Gaspé Peninsula.

Cobalt is produced as a by-product of nickel-copper operations in the Sudbury and Thompson regions, and indium from a single mine in southern British Columbia. Cadmium is the by-product of operations at seven mines scattered across Canada in Newfoundland, New Brunswick, Ontario, British Columbia (2), and the Yukon (2). Other non-ferrous metals are each produced at a single location. Magnesium and calcium are mined by open-pit at Haley, Ontario; the rest are mined underground: Tungsten at Tungsten, NWT; tantalum and cesium at Bernic Lake, Manitoba; columbium at Chicoutimi, Quebec, and titanium at Havre-St-Pierre, Quebec.

The demand for additive refractory and reactive metals (cobalt, columbium, molybdenum, silicon, tantalum, titanium, and tungsten) is centred primarily in the iron and steel industry. A number of these act as deoxidizers of molten steel, some impart specific physical and chemical properties to the finished steel and others are used as refractories. Many also find important applications as pure metal, non-ferrous alloys, or chemical compounds.

Precious Metals

Much of the ***gold*** and ***silver*** is produced as by-products of major nickel, copper, lead, and zinc mines. The major producers (*see* Map 8d) are concentrated in northern Ontario, northwestern Quebec, British Columbia, the Yukon and Northwest Territories. There are 21 operating gold mines (January, 1980), of which 16 are located in Ontario and Quebec and four in the N.W.T., producing 39, 27, and 10 percent respectively of total production (*see* Table 12). Lode gold mines predominate in these areas, and are usually underground operations. However, by-product gold from 25 base-metal operations, particularly those associated with lead, zinc, and copper mines, predominate in British Columbia, and the Atlantic Provinces, with a single operation in the Yukon. Placer-gold operations are confined to British Columbia and the Yukon. In 1978, there were 75 full-time placer mining (*see* Map 4) and 15 part-time sluicing operations in the Yukon (Marchand *et al.*, 1978).

Major silver mines are found in Ontario (3), British Columbia (3), and the Yukon (1), however, base-metal mines (38 in all) producing silver as a by-product (87 percent of the silver) are found in all provinces and territories except Prince Edward Island, Nova Scotia, and Alberta. All the major silver mines are underground operations, as are the majority of the by-product operations. The leading silver producers are Ontario (37 percent), British Columbia (18.4 percent), New Brunswick (15.5 percent), and the Yukon (10.4 percent) from all mine sources.

NON-METALLIC MINERALS

The three groups of non-metallic minerals (industrial minerals, construction materials, and fertilizers) combined account for 28 percent of the total value of all mining production and, in total tonnage extracted, far exceed the total for the metallic- and energy-related mineral categories. The principal commodities produced in each category, annual production rates, number of producing mines, and general location are listed in Table 13. Only the major industrial mineral and fertilizer (potash) producing areas have been indicated (*see* Map 8a).

Industrial Minerals

Industrial minerals generally have higher unit values and are mined in smaller quantities than the construction materials (*see* Table 12). Mine operations tend to be concentrated in the more-settled areas of Canada, particularly the Southern Interior Plains (LRZ III.3), St. Lawrence Lowlands (LRZ VI.1 and VI.2), and Appalachian Region (LRZ VII) (*see* Map 8a). In terms of product value, asbestos production accounts for 57 percent of the industrial mineral receipts from mines in Quebec, Ontario, Newfoundland, and British Columbia. Almost 90 percent of asbestos production is in Quebec. Although gypsum is more widely distributed, almost 70 percent is produced from six mines in Nova

TABLE 13. NON-METALLIC MINERAL PRODUCTION: 1980

	Annual Production (tonnes X 10^3)	Number of Mine Operations	Location
Industrial Minerals			
Asbestos	1,335	11	Que., Ont., B.C., Nfld.
Barite	NA	5	Alta., B.C., Yukon
Bentonite	NA	3	Alta., Man., Sask.
Gypsum	7,209	14	N.B., N.S., Nfld., Ont., Man., B.C.
Mica	NA	1	Que.
Nepheline Syenite	592	2	Ont.
Salt	7,029	8	N.S., Ont., Alta., Sask.
Sodium Sulphate	496	9	Sask., Alta.
Silica	NA	13	Nfld., Que., Ont., Man., Sask., Alta., B.C.
Soapstone, talc	87	4	Que., Ont.
Construction Materials			
Sand and gravel	327,860	numerous	All provinces
Stone	103,281	numerous	All provinces
Cement	10,497	21	All provinces except Man. and P.E.I.
Lime	2,063	15	N.B., Que., Ont., Man., Alta., B.C.
Fertilizers			
Potash	7,532	10	Saskatchewan
Peat	488	NA	All provinces except P.E.I. and Nfld.

Sources: Dep. Energy, Mines and Resources, 1977, 1979d, Canadian Mining Journal, 1981.

Scotia. The only other major concentration of single products are silica from seven sites in Quebec and sodium sulphide from six sites in Saskatchewan. One sodium sulphide site is located in Alberta. Over 80 percent of the mines use open-pit methods to extract the mineral, the remainder use underground methods including solution mining for salt. Underground methods are used for barite, asbestos, sodium sulphide, rock salt, dolomite, talc, and gypsum.

Construction Materials

The construction materials industry exists in all parts of Canada where there is construction activity. Indeed, the demand for aggregates is very closely associated with the construction industry. Road construction and maintenance consume approximately one-half of the sand and gravel and one-third of the crushed stone produced in 1975. The manufacture of building materials — cement and concrete products — consumed the second largest amount. Under the circumstances it is not surprising that the main markets are urban centres, and that most extraction sites are found concentrated within the urban-rural fringe. Their location is largely a reflection of transportation, the single most costly factor in the production and distribution of aggregates to market. A summary of a Statistics Canada survey of aggregate producers indicated that:

". . .transportation costs, expressed as a percentage of the delivered value of sand and gravel shipments, were 44 percent in 1974 and 40 percent in 1975. Similarly, the share of transportation costs for stone (including some stone not used for aggregates) was 25 percent in 1974 and 23 percent in 1975". (Canadian Transportation Commission, 1978).

An estimated 97 percent of all sand, gravel, and stone were moved by truck, with water carriers and rail carrying the remainder. Shipments of aggregates consisted of approximately two-thirds sand and gravel and one-third stone. In 1980, 327 million tonnes of sand and gravel were shipped compared to 103 million tonnes of stone, for a total of 430 million tonnes, or a per capita average of approximately 17 tonnes. In terms of production, central Canada (Ontario and Quebec) accounts for 70.5 percent of all aggregate production (Canadian Mining Journal, 1981) and consumption undoubtedly parallels this figure.

Data available on the number, size, and location of pits and quarries (including abandoned operations) is too limited to provide an accurate nation-wide assessment of this sector of the mining industry. Therefore, in order to indicate the extent of construction material operations in Canada, a limited inventory of pits and quarries in Eastern Canada was conducted as a part of this study (Environment Canada, 1977). The inventory concentrated on those sites in Ontario, Quebec, New Brunswick, Nova Scotia, Prince Edward Island and Newfoundland which, combined, account for 78 percent aggregate production in Canada, and which are located near populated centres (greater than 500 inhabitants). Of 4,997 pits and quarries identified, more than 90 percent were sand and gravel pits. This figure included currently operating sites as well as abandoned or temporary closed sites. Eighty-one percent of the sites were located in Ontario and Quebec. Sixty-eight percent of the sites were located within 8 kilometres of a populated centre and 46 percent were within 5 kilometres (Table 14). There were only 36 lime and cement operations across Canada in 1978 which utilized their own quarries for materials. The remainder obtained their supplies from other independent quarries.

The Canadian Transport Commission (1978) indicated that there appeared to be sufficient mineral aggregate reserves to meet future demands in all regions of Canada except Prince Edward Island and the Macken-

Limestone quarry, south of Ottawa, Ontario
Robert Audet, Environment Canada

zie District of the Northwest Territories. However, local shortages are appearing in St. John's, Newfoundland; Sydney and Halifax, Nova Scotia; Moncton, New Brunswick; the Gaspé and Magdalen Islands in Quebec; southwestern Ontario; Portage la Prairie, Manitoba; Swift Current and Weyburn, Saskatchewan; around Coronation, Alberta; and in the greater Vancouver region, British Columbia.

For example, in the Fraser Lowland and Greater Vancouver market areas, urban encroachment and a variety of restrictive land use regulations have created a

TABLE 14. SUMMARY OF LAND AREA DISTURBED AND NUMBER OF PITS AND QUARRIES IN EASTERN CANADA: WITHIN 8 KM OF POPULATED CENTRES

PROVINCE/TERRITORY	DISTANCE FROM POPULATED CENTRE					
	0.16 km		0.16 - 4.8 km		4.8 - 8 km	
	Area (ha)	No. Pits	Area (ha)	No. Pits	Area (ha)	No. Pits
Northern Ontario	28	2	1,641	123	565	55
Western Ontario	1,171	54	3,461	405	648	111
Central Ontario	773	70	2,774	350	1,482	253
Eastern Ontario/Ottawa Valley	528	62	2,035	438	602	140
Northwestern Quebec	6	1	118	34	116	23
Quebec St. Lawrence/ Eastern Townships	889	56	2,927	320	1,782	226
Quebec/Lower St. Lawrence	52	3	269	71	53	29
New Brunswick	45	12	307	91	105	34
Nova Scotia	44	9	755	61	163	274
Prince Edward Island	10	3	75	31	19	4
Newfoundland	29	8	163	54	29	11
TOTAL	3,575	280	14,525	1,978	5,564	1,160

Source: Environment Canada, 1977.

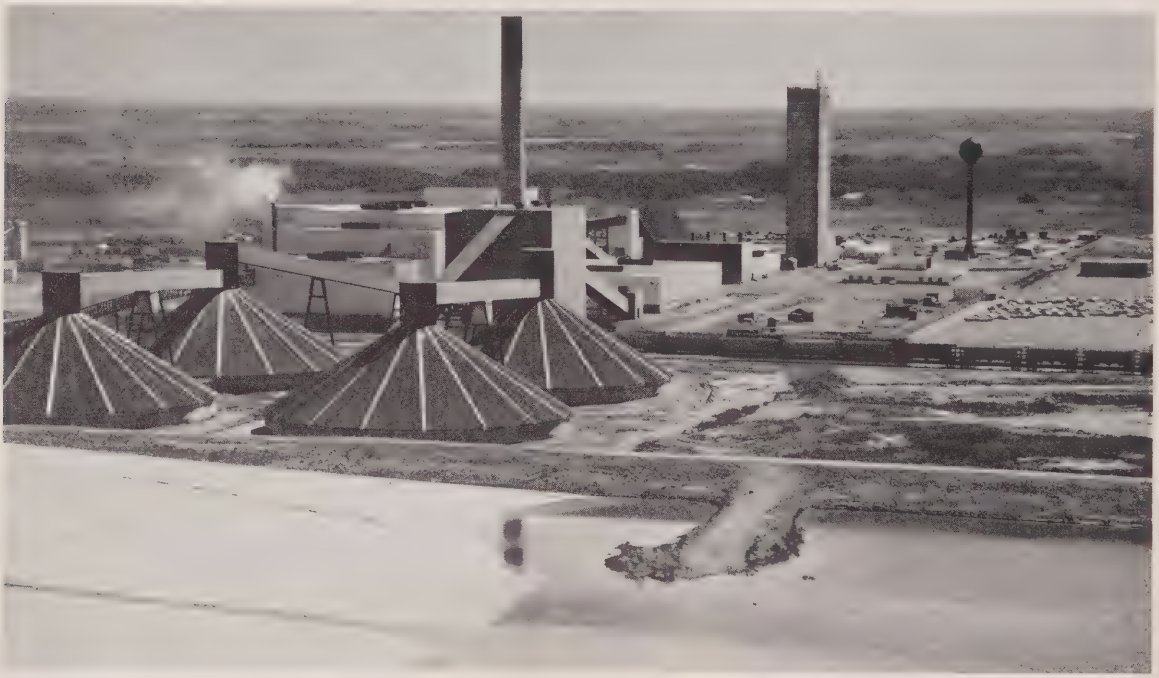
problem where, of the 16 municipalities, seven have no available reserves of aggregates at all and seven have from two to ten years supply at 1978 production levels (Hora, 1981). Already 5 million of 12 million tonnes per year consumed commercially are imported, of which 4 million tonnes is brought by barge from as far as 110 kilometres away.

Due to local shortages and pressure from other land use activities, the provincial and federal agencies have been actively engaged in programs to locate, quantify, and classify all existing and potential new sources of aggregates. Essential to the program has been the need for better land use management with regard to aggregate resources. Towards this end, many of the provinces are in the process of formulating a policy for aggregate development within a regional framework. This has entailed changes in existing municipal and planning regulations as well as incorporating these changes into land use policies and resource management programs. In addition, solutions to local shortages have required further research into the increased use of rail and water transport of aggregates over longer distances.

Fertilizers

Saskatchewan is the only current producer of ***potash*** (KCL or muriate of potash) in Canada (*see* Map 8a). The potash deposits in Saskatchewan are part of the Prairie evaporate formation that stretches from North Dakota northwest across central Saskatchewan (LRZ II.3). Only a small extension of the deposit extends across the border into Manitoba. All the potash that can be mined by conventional means (underground shaft) is located in Saskatchewan, at depths less than 1,067 metres. The potash in North Dakota is too deep to be removed economically by present-day technology. The layers now solution-mined in Saskatchewan are 2 to 3.5 metres thick and contain 40 to 50 percent sylvite or 24 to 30 percent K_2O (potassium oxide). Conservative estimates of recoverable reserves are 118 billion tonnes KCL or after refining, 70 billion tonnes of K_2O (Saskatchewan Dep. of Mineral Resources, 1976).[9] In 1979, approximately 7.5 million

[9] Figures for tonnage of potash produced or sold are K_2O tonnes (potassium oxide) equivalent to 60 percent of the actual weight of 1 tonne of potash (KCL) mined.



Potash mine, Esterhazy, Saskatchewan
NFB — Phototheque — ONF, George Hunter

tonnes of K_2O was produced in Saskatchewan, up from 6.3 million tonnes in 1978 (Canadian Mining Journal, 1981). Of the ten mines in operation, nine were underground and one used a solution-extraction technique.

The only other potash deposits in Canada were recently discovered in the Sussex area, northeast of St. John's, New Brunswick (LRZ VII). Potash deposits were found at a depth of between 457 and 762 metres, with a K_2O content of 25 to 30 percent, approximately the same as Saskatchewan deposits (Branch, 1979). The most significant differences are the irregular, inclined beds in New Brunswick rather than the continuous flat beds in Saskatchewan.

The other major fertilizer that can be classed as a product of mining is ***peat***. Organic peat deposits cover more than 225,000 square kilometres of Canada's land surface (Clayton *et al.*, 1977). The deposits vary considerably in thickness and are widespread in the cold cryoboreal and boreal climatic zones (*see* Map 5), where almost 60 percent are located in northern forested areas subject to permafrost conditions. Canada has the second largest peat resource in the world but has utilized only a very small fraction of the total resource. However, peat as a future fuel source may become more attractive in regions deficient of energy sources. Most of the current production is located in the southern regions of the provinces where, with access to local markets, it is almost exclusively used for horticultural purposes. Ripley *et al.* (1978) estimate that only 33 hectares have been affected by stripping operations. Preliminary production figures for 1980, indicate that 488,000 tonnes were produced with a value of approximately $42.5 million (Canadian Mining Journal, 1981). Quebec and New Brunswick are the major producers accounting for 44 and 29 percent respectively.

ENERGY-RELATED MINERALS

Oil Sands

Canada's oil sands and heavy-oil resources are located almost exclusively in Alberta (with small exten-

TABLE 15. SUMMARY OF OIL SANDS AND HEAVY-OIL RESOURCE ESTIMATES

	LLOYDMINSTER Enhanced recovery "50/50" probability	COLD LAKE In situ	ATHABASCA TYPE	
			Mining	In situ
Crude Oil (Bitumen)				
In Place - Billions of Metres^3	2	26	12	114
- Billions of Barrels	12	165	51	715
Recoverable Upgraded				
Oil - Billions of Metres^3	0.24 - 0.72	2.4 - 0.72	4.3	6.3 - 22.2
- Billions of Barrels	1.5 - 4.5	115 - 30	27	40 - 140
Status of Recovery Technology	Near commercial	Technically proven	Commercial operation	Pilot stage
Current Economic Viability	Probably economic	May be marginal at world oil prices	Economic at world prices	Unknown
Anticipated Timing	Early 1980's	Mid to late 1980's	Ongoing	Late 1980's - early 1990's

Source: Dep. Energy, Mines and Resources Canada, 1978.

sions into Saskatchewan, LRZ II.2). There are four major deposits (Map 9), Athabasca, Cold Lake, Peace River, and Wabasca underlying 4.9 million hectares (7.5 percent) of Alberta (Simpson-Lewis *et al.*, 1979). Only the Athabasca oil sands are exploitable using conventional surface-mining techniques. Using current technology, surface extraction is limited to overburden deposits less than 46 metres thick. Less than 10 percent of the 2.3 million hectares of the Athabasca sands can be exploited by surface extraction. Therefore future expansion there, as well as in the other three deposits, will depend on *in situ* (underground) recovery involving the heating of the oil to a temperature at which it will begin to flow. Table 15 summarizes oil sands mines operational at this time. The Great Canadian Oil Sands Co. Ltd. (now Suncor) project has been fully operational since 1967 producing 6,400 cubic metres/day of synthetic crude oil, whereas the Syncrude Canada Ltd. commenced partial production in 1978. Full production of 20,000 cubic metres/day (125,000 barrels/day) is expected between 1980 and 1982 (Dep. Energy, Mines and Resources, 1979*b*).

Coal

Coal deposits are known to exist in all Canadian provinces and territories except Quebec and Prince Edward Island. They occur within sedimentary basins of different age, rank, size, and quality. Due to the diversity in the quality of coal, a classification has been

TABLE 16. 1977 COAL RESERVES IN CANADA BY RANK

MINEABLE COAL[1] (megatons)					RECOVERABLE COAL[2] (megatons)				
Province/ Territory	Rank[3]	Underground	Surface	Total	Province/ Territory	Rank[3]	Underground	Surface	Total
Nova Scotia	hvb	364	6	370	Nova Scotia	hvb	89		89
New Brunswick	hvb		46	47	New Brunswick	hvb		33	33
Ontario	lig		218	218	Ontario	lig			
Saskatchewan	lig		2,150	2,150	Saskatchewan	lig		1,720	1,720
Alberta	sub	1,347	5,981	7,328	Alberta	sub	N/A	N/A	2,182
	h-mvb	424	513	937		h-mvb	84	155	239
	h-mvb	562	958	1,520		l-mvb	64	227	291
British Columbia and Yukon	lig		839	839	British Columbia and Yukon	lig		397	397
	h-mvb	54	492	546		h-mvb	N/A	N/A	51
	l-mvb	582	1,555	2,137		l-mvb	44	860	904
CANADA TOTAL	lig		3,207	3,207	CANADA TOTAL	lig		2,117	2,117
	sub	1,347	5,981	7,328		sub	N/A	N/A	2,182
	bit	1,986	3,570	5,556		bit	N/A	N/A	1,607

1 MINEABLE COAL (Level 1) is that part of the measured and indicated resources of immediate interest within a coal deposit, that can be considered for mining using current technology, and playing broad economic judgment only to the mining method.

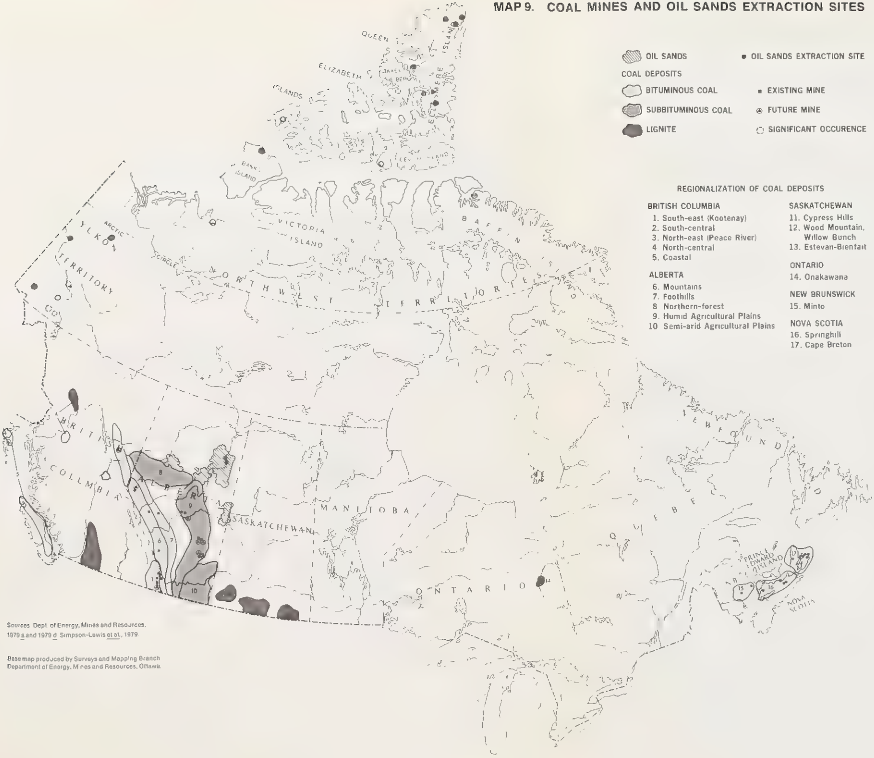
2 RECOVERABLE COAL (Level 2) is that part of MINEABLE COAL (Level 1) that could be recovered as run-of-mine coal with current technology and at current market prices. The coal deposit must be legally open to mining, and the necessary infrastructure must be in place or could be amortized through coal sales.

3 lig -- lignitic; bit -- bituminous; sub -- Subbituminous; hvb -- high-volatile bituminous; hvb -- low-volatile bituminous; mvb -- medium volatile bituminous.

N/A Not available.

Source: Bielenstein _et al._, 1979.

MAP 9. COAL MINES AND OIL SANDS EXTRACTION SITES



Sources Dept. of Energy, Mines and Resources, 1979 a and 1979 d Simpson-Lewis et al., 1979.

Base map produced by Surveys and Mapping Branch Department of Energy, Mines and Resources, Ottawa.

TABLE 17. APPROXIMATION OF PRESENT AND FUTURE CANADIAN COAL PRODUCTION FROM SURFACE AND UNDERGROUND MINES
(Tonnes X 10^6)

Province/ Territory	1977*		1990 - 2000	
	Surface	Underground	Surface	Underground
British Columbia	10.6	0.8	24.3	4.0
Alberta	12.1	1.7	41.6	5.3
Saskatchewan	5.5	0.0	16.0	-
Ontario	-	-	4.7	-
New Brunswick	0.3	-	1.3	-
Nova Scotia	0.02	2.6	0.13	4.98
Yukon Territory	-	0.1	0.0	0.01
CANADA	28.5	5.2	88.0	14.3
PERCENTAGE	84.5	15.5	86.0	14.0

* Based on raw coal production.

Source: Dep. of Energy, Mines and Resources, 1979a, Blakeman, 1980.

established where it is measured by heat value, volatile matter, calorific value, and the amount of fixed carbon. In Canada, three groups of coal have been identified — lignite, sub-bituminous, and bituminous (high-volatile, and low-volatile subgroups) — in order of increasing heat value. The distribution of these coal deposits and those regions currently being mined are indicated on (*see* Map 9). The most recent estimates of Canada's mineable and recoverable coal reserves are summarized in Table 16, from which it can be seen that Canada's total mineable coal is estimated to be approximately 16 billion tonnes. Approximately 6 billion tonnes could be recovered as run-of-mine coal with current technology and at current market prices. Estimated coal resources, both measured and inferred, are approximately 474 billion tonnes (Bielenstein *et al.*, 1979). Over 97 percent of the total recoverable coal resource is located in the three western provinces.

Preliminary estimates for 1980 indicate that Canada produced a total of 36.5 million tonnes of saleable metallurgical and thermal coal from 26 mines, up about 9 percent over the 1979 figure of 33.2 million tonnes (Alysworth, 1981)[10]. Alberta led coal production with 47 percent of the total, followed by British Columbia and Saskatchewan with 28 and 15 percent respectively. Both surface and underground mining were utilized. Underground techniques, including long wall, room and pillar, and hydraulic mining, were used in British Columbia, Alberta, Nova Scotia, and the Yukon. Strip-mining operations are carried out on the generally level plains of New Brunswick, Alberta, and Saskatchewan, from near-surface coal seams. Open-pit mine operations are used to extract coal from deeply buried, steeply dipping of extensively folded seams in the mountainous terrain of Alberta and British Columbia. These operations usually leave deep, steep-sided pits.

The significance of surface *versus* underground operations is illustrated in Table 17 where estimates of present and future production are shown. Approximately 85 percent of present and future production is from surface mining, the significance being that surface operations are highly visible, utilize more-extensive land areas and have the greater potential for land degradation.

[10] Saleable Coal: is coal deliverable to the end-user of "free on board". It represents clean coal plus any run-of-mine coal for sale where a preparation plant is required, and recoverable coal where no preparation is planned. The 36.5 million tonnes of saleable coal represents on average about 85 percent of the run-of-mine coal extracted.

Bucket wheel excavator at oil sands site, Fort McMurray, Alberta
NFB — Phototheque — ONF, George Hunter

Uranium

In 1978, Canada had six uranium producers (Map 10): Denison Mines Ltd., Rio Algom Ltd., Madawaska Mines Ltd., and Agnew Lake Mines Ltd. in Ontario (LRZ IV.1); and Eldorado Nuclear Ltd. and Gulf Minerals Canada Ltd./Uranez Canada Ltd. in Saskatchewan (LRZ IV.2). Production of uranium in 1979 amounted to 6,811 tonnes, compared to 6,803 tonnes in 1978 (Williams, 1980).

A seventh mine opened in May, 1979, near Uranium City (Cene Ltd.), but closed due to a fire, and its future is still uncertain. The Rabbit Lake mine in Saskatchewan is an open-pit operation, and the Agnew Lake mine is a combined underground and surface-heap leaching operation. However, unresolved technical problems with the surface-heap leaching operation led to it being phased out by early 1980 (Williams, 1980). The remainder of the mines use underground methods.

Table 18 summarizes the most-recent assessment of Canada's uranium resources by the Uranium Resource Appraisal Group (URAG) of the Department Energy, Mines and Resources, 1979*c*. Of the total mineable resources (measured, indicated, and inferred) about 68 percent are in Ontario and 27 percent in Saskatchewan. Estimates of additional resources were made in expected extensions of existing well-explored deposits believed to exist (*see* Figure 15). About 42 percent of the prognosticated resources are located in Ontario, some 35 percent in Saskatchewan, and 14 percent in the Northwest Territories.

TABLE 18. 1978 ESTIMATE OF CANADA'S URANIUM RESOURCES

Mineable at Uranium Prices**	Tonnes U (000's) Contained in Mineable Ore*			
	Reasonably Assured**		Estimated Additional***	
	Measured	Indicated	Inferred	Prognosticated
Up to $125/kg U	76	139	223	147
$125 to 175/kg U	4	16	79	279
TOTAL	80	155	302	426

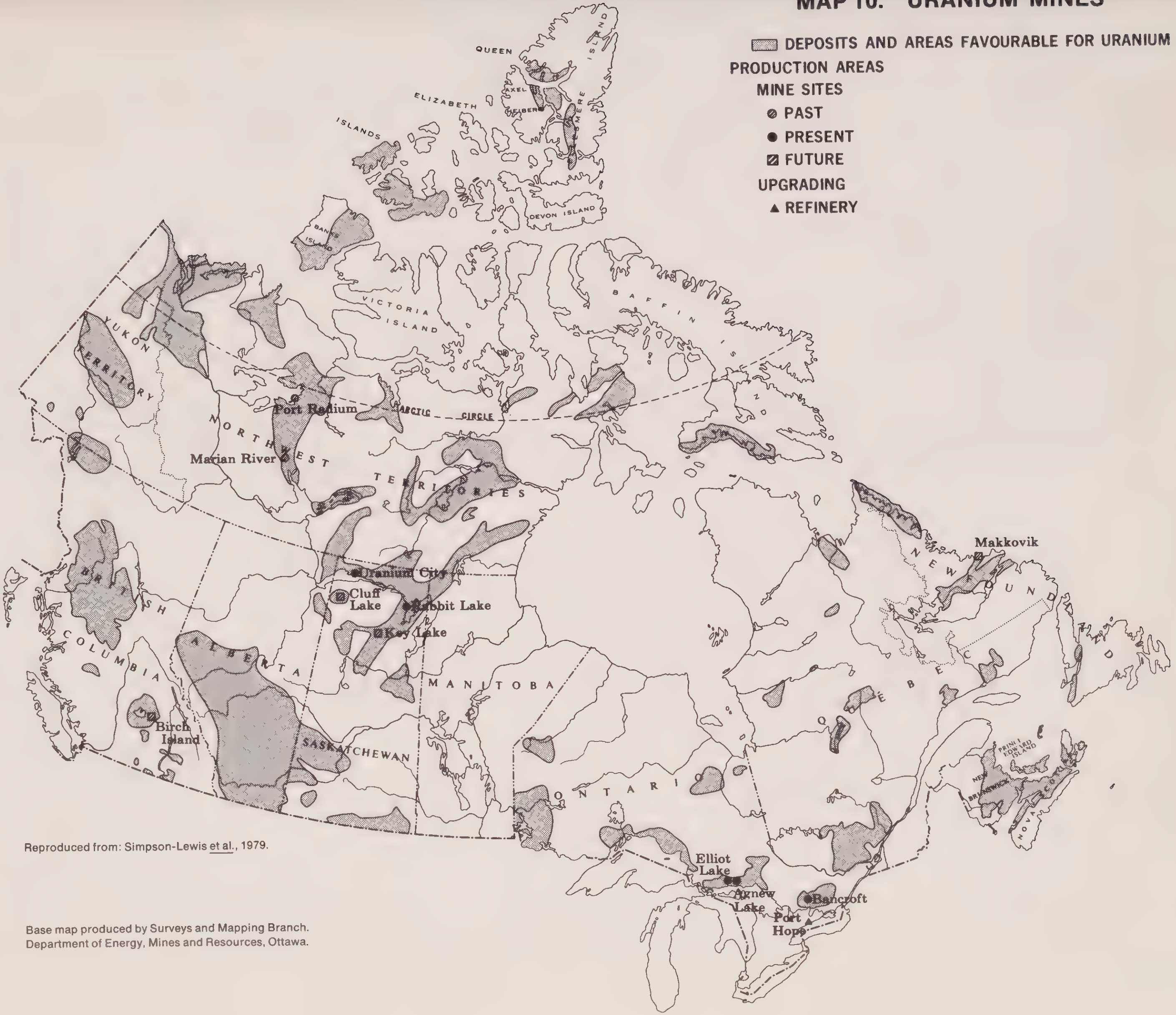
* Uranium recoverable from such ore will be less, because of milling losses (<u>see</u> text).

** The dollar figures refer to the market price of a quantity of uranium concentrate containing 1 kg of elemental uranium. The prices were used in determining the cut-off grade at each deposit, taking into account mining methods and milling losses.

*** International Resource terms employed by the Nuclear Energy Agency of OECD and the International Atomic Energy Agency; for purposes of International comparison "<u>Reasonably Assured Resources</u> refers to uranium that occurs in known mineral deposits of such size, grade, and configuration that it could be recovered within the given production cost ranges, with currently proven mining and processing technology. Estimates of tonnage and grade are based on specific sample data and measurements of the deposits and on knowledge of deposit characteristics. Reasonably Assured Resources have a high assurance of existence and in the cost category below $80/kg U ($30/lb U 0) are considered <u>reserves</u> for the purpose of this report. <u>Estimated Additional Resources</u> refers to uranium in addition to Reasonably Assured Resources that is expected to occur, mostly on the basis of direct geological evidence, in extensions of well-explored deposits, little-explored deposits, and undiscovered deposits believed to exist along a well-defined geological trend with known deposits. Such deposits can be identified, delineated, and the uranium subsequently recovered, all within the given cost ranges. Estimates of tonnage and grade are based primarily on knowledge of the deposit characteristics as determined in its best-known parts or in similar deposits. Less reliance can be placed on the estimate in this category than for Reasonably Assured Resources".

Source: Dep. Energy, Mines and Resources, 1979<u>c</u>.

MAP 10. URANIUM MINES



Reproduced from: Simpson-Lewis et al., 1979.

Base map produced by Surveys and Mapping Branch.
Department of Energy, Mines and Resources, Ottawa.

FUTURE MINE DEVELOPMENTS

METALLIC MINERALS

The location of the major areas containing metallic mineral reserves with potential for future mine development are shown on Map 11. The data presented are not a comprehensive inventory, nor do they include new discoveries made within the past five years. The survey represents the best available data on mineral deposits which are either economically exploitable today or are within reach of becoming so within the next 20 years, as a result of predicted economic and technical changes. The objective of the map is to identify the geographic areas in which mining is likely to occur in the next 20 years rather than to attempt to quantify and locate the reserves in terms of type of deposit, tonnages, or grades or to forecast when production may commence at the respective locations. The constantly changing nature of mineral reserves and resources available for use — particularly through new discoveries and changing reserve estimates — coupled with the polymetallic nature of deposits prohibits any precise determination of future mine developments beyond the 1980's. However, it is possible to give some indication of the regional distribution of probable new mining operations.

The following groups of minerals were investigated during the course of the survey:[11]

Group I	Group II	
copper	antimony	mercury
lead	beryllium	niobium (columbium)
molybdenum	bismuth	platimum group metals
nickel	chromium	silver
uranium	gold	tantalum
zinc	lithium	titanium
	manganese	

Iron-ore deposits that did not contain significant amounts of one or more of the above metals were excluded. In addition, some of the mineral deposits (*see* Map 11.) contain more than one mineralization area with mining potential, and, therefore, the actual number of individual mine sites could be greater. On the map are located 235 mineral deposits according to the major mining regions, two thirds of which are in various stages of development. An additional 238 deposits were identified in the same report as being unlikely to be developed before 2000 A.D. The distribution of potential metallic mine development according to Land Resource Zones is illustrated in Map 12. However, an Inventory of Canadian Mineral Deposits Not Being Mined In 1980 recently published (Dep. Energy, Mines and Resources, 1980) reveals a significant increase in exploration and discovery of new deposits, from 473 in 1975 to more than 1300 in 1980 (includes some non-metallic industrial minerals). Unlike the earlier survey (Annis *et al.*, 1976) this 1980 inventory did not indicate whether or not the deposits were in various stages of development.

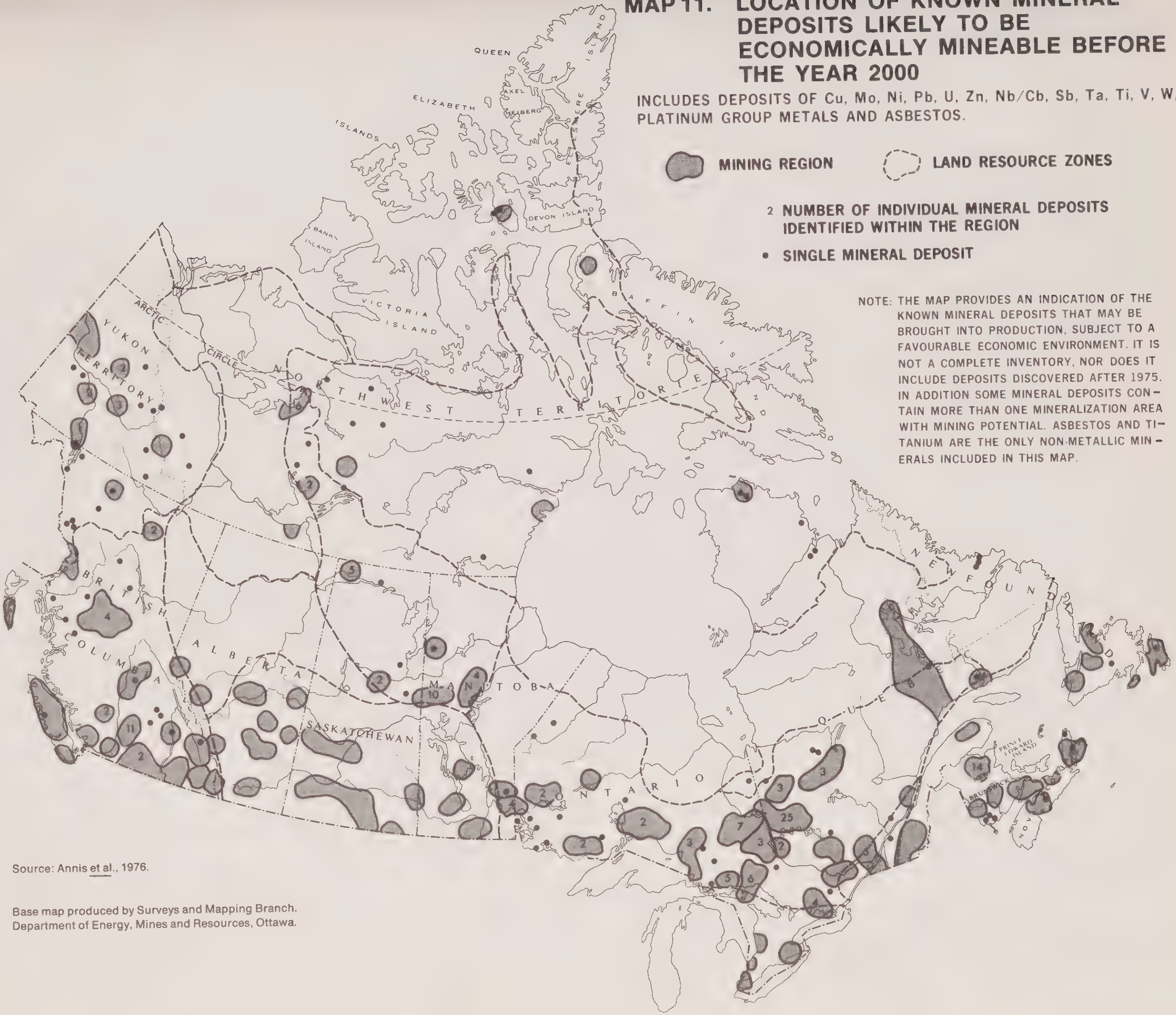
A comparison of the distribution of the mineral deposits known in 1975 and 1980 (Map 13) with the distribution of mines currently operating (Map 14) reveals that the general pattern of exploration and potential mine development has not changed significantly. The heaviest concentrations of known deposits continue to be in the southern half of the Canadian Shield (Land Resource Zone IV.1 and IV.2) and in the southern Cordilleran (LRZ 1.2). There is a slight increase in activity on a percentage basis (five percent) in the southern half of the Shield (LRZ IV.1) in Ontario and Quebec, and in the Appalachian Zone (LRZ VII). A slight decrease has occurred to the west and southwest of Hudson Bay in the shield (LRZ IV.2 and IV.3).

In 1976, Martin *et al.*, (1976) forecast future requirements for seven major metals to the year 2000 (nickel, copper, lead, zinc, molybdenum, iron, and uranium oxide) based on the results of an earlier study (Dep. Energy, Mines and Resources, 1975). The forecasts were based on assumptions of continued world economic growth with no long-term production difficulties in major producing companies, no marked changes in world marketing patterns, and no major changes in population growth trends. The number of new mine requirements during the twenty-five year period 1976 to 2000 A.D. was estimated at 228 (about the same number of new discoveries that was made during the 25-year period 1945 to 1970). Iron and nickel reserves were found to be sufficient to meet future requirements till the year 2000. Therefore, the new mine requirements did not include estimates for new nickel and iron-ore mines. Forecast steel demand in Canada is projected to rise from 16 million tonnes in 1980, to 17.5 in 1985 and 20 million tonnes by the year 2000 (Dep. Energy, Mines and Resources, 1979*e*). Very little increase in exports of iron ore is expected in the next decade due to extensive competition from overseas competitors in Africa, Brazil, India, and Australia. In addition, United States iron-ore producers are closer to Canadian steel producers in southern Ontario, and

[11] Group I minerals have been studied in greater detail than Group II, providing a more accurate data base on it. This reflects the overall importance of this group to mineral production in Canada accounting for approximately two thirds of the value of all mining production. Asbestos was the only non-metallic mineral included in this survey. However, it has been dealt with in the following section under Non-Metallic Minerals in this study.

MAP 11. LOCATION OF KNOWN MINERAL DEPOSITS LIKELY TO BE ECONOMICALLY MINEABLE BEFORE THE YEAR 2000

INCLUDES DEPOSITS OF Cu, Mo, Ni, Pb, U, Zn, Nb/Cb, Sb, Ta, Ti, V, W, PLATINUM GROUP METALS AND ASBESTOS.

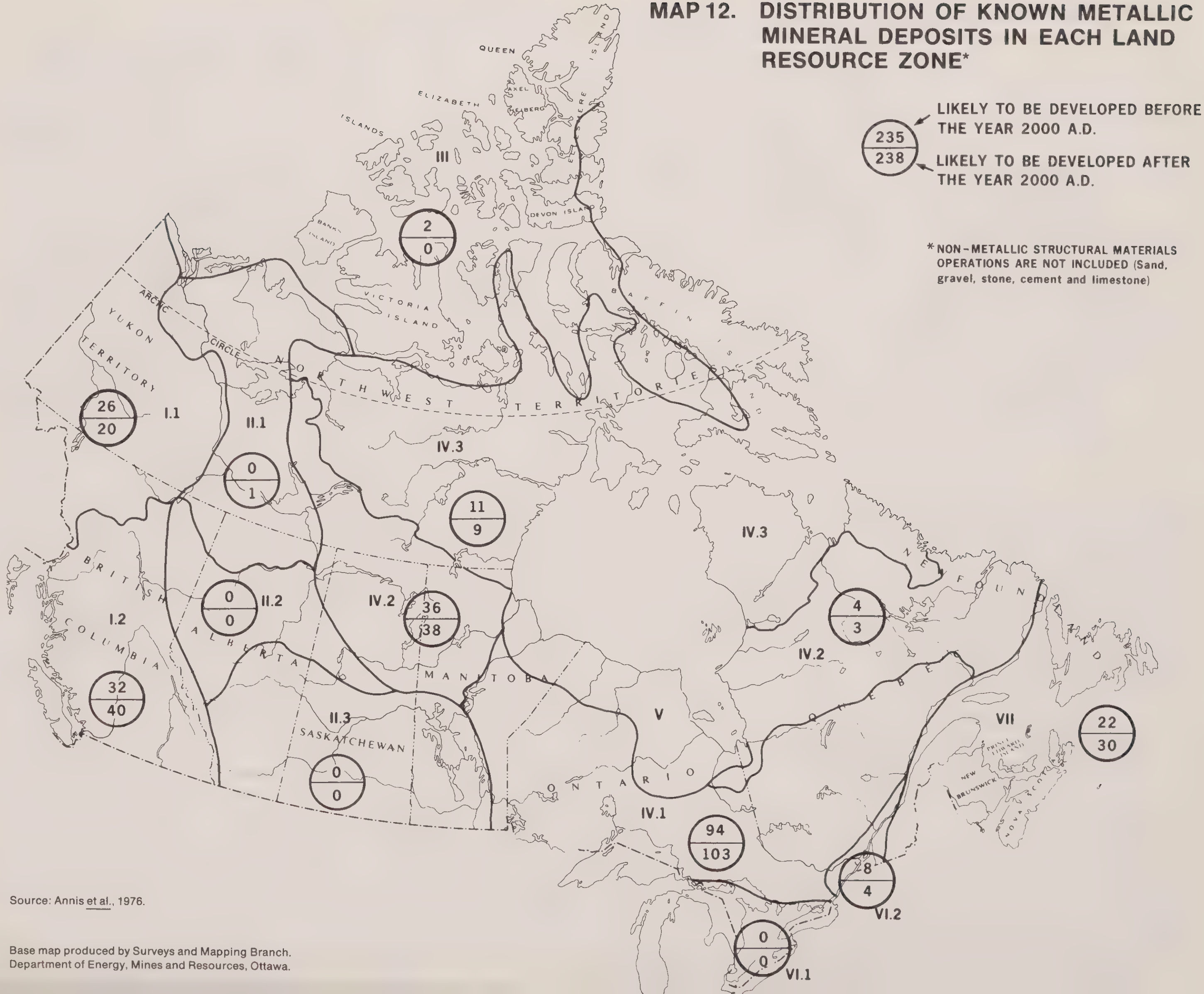


NOTE: THE MAP PROVIDES AN INDICATION OF THE KNOWN MINERAL DEPOSITS THAT MAY BE BROUGHT INTO PRODUCTION, SUBJECT TO A FAVOURABLE ECONOMIC ENVIRONMENT. IT IS NOT A COMPLETE INVENTORY, NOR DOES IT INCLUDE DEPOSITS DISCOVERED AFTER 1975. IN ADDITION SOME MINERAL DEPOSITS CONTAIN MORE THAN ONE MINERALIZATION AREA WITH MINING POTENTIAL. ASBESTOS AND TITANIUM ARE THE ONLY NON-METALLIC MINERALS INCLUDED IN THIS MAP.

Source: Annis et al., 1976.

Base map produced by Surveys and Mapping Branch.
Department of Energy, Mines and Resources, Ottawa.

MAP 12. DISTRIBUTION OF KNOWN METALLIC MINERAL DEPOSITS IN EACH LAND RESOURCE ZONE*

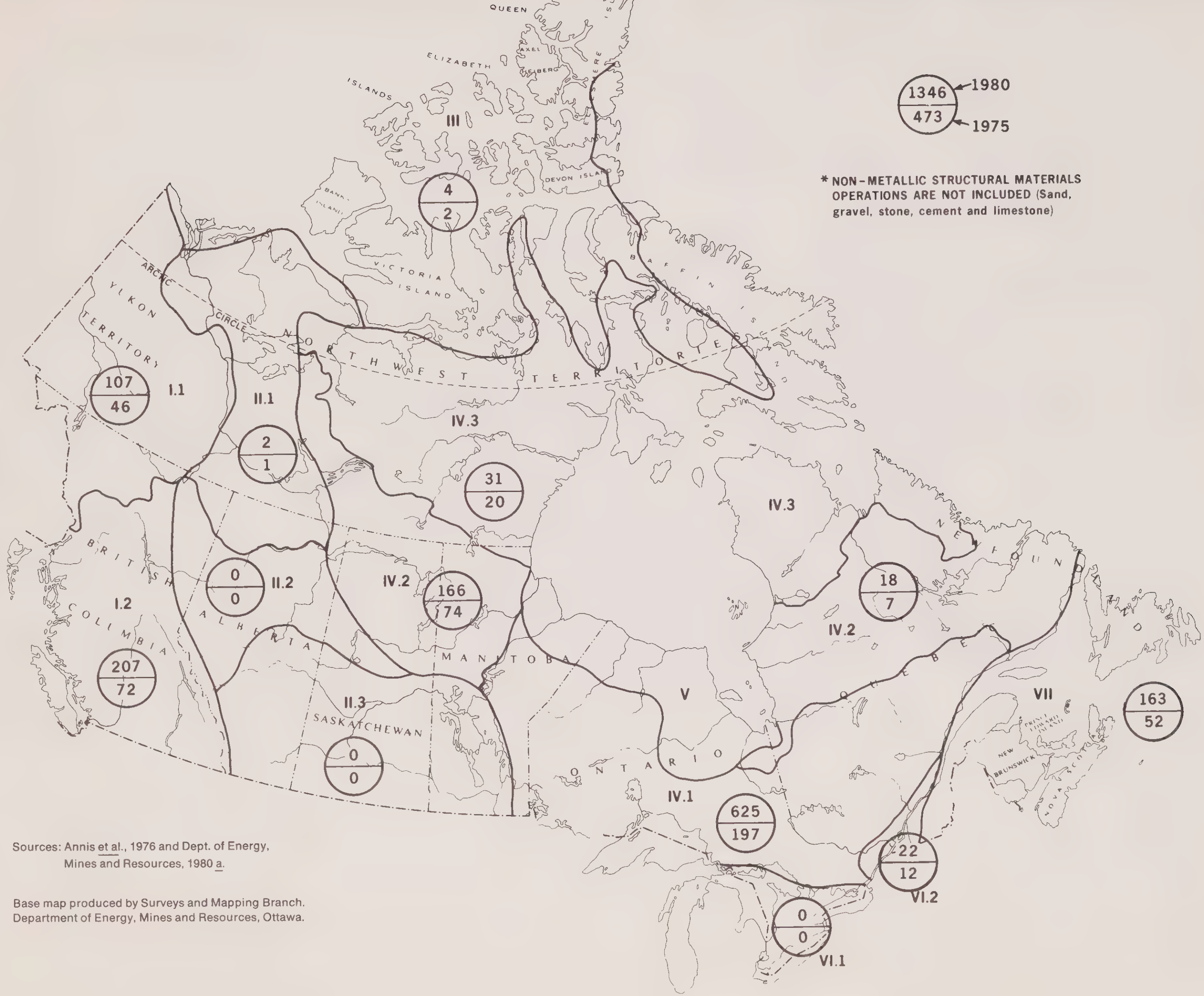


*NON-METALLIC STRUCTURAL MATERIALS OPERATIONS ARE NOT INCLUDED (Sand, gravel, stone, cement and limestone)

Source: Annis et al., 1976.

Base map produced by Surveys and Mapping Branch. Department of Energy, Mines and Resources, Ottawa.

MAP 13. NON-PRODUCING CANADIAN MINERAL DEPOSITS IN EACH LAND RESOURCE ZONE*

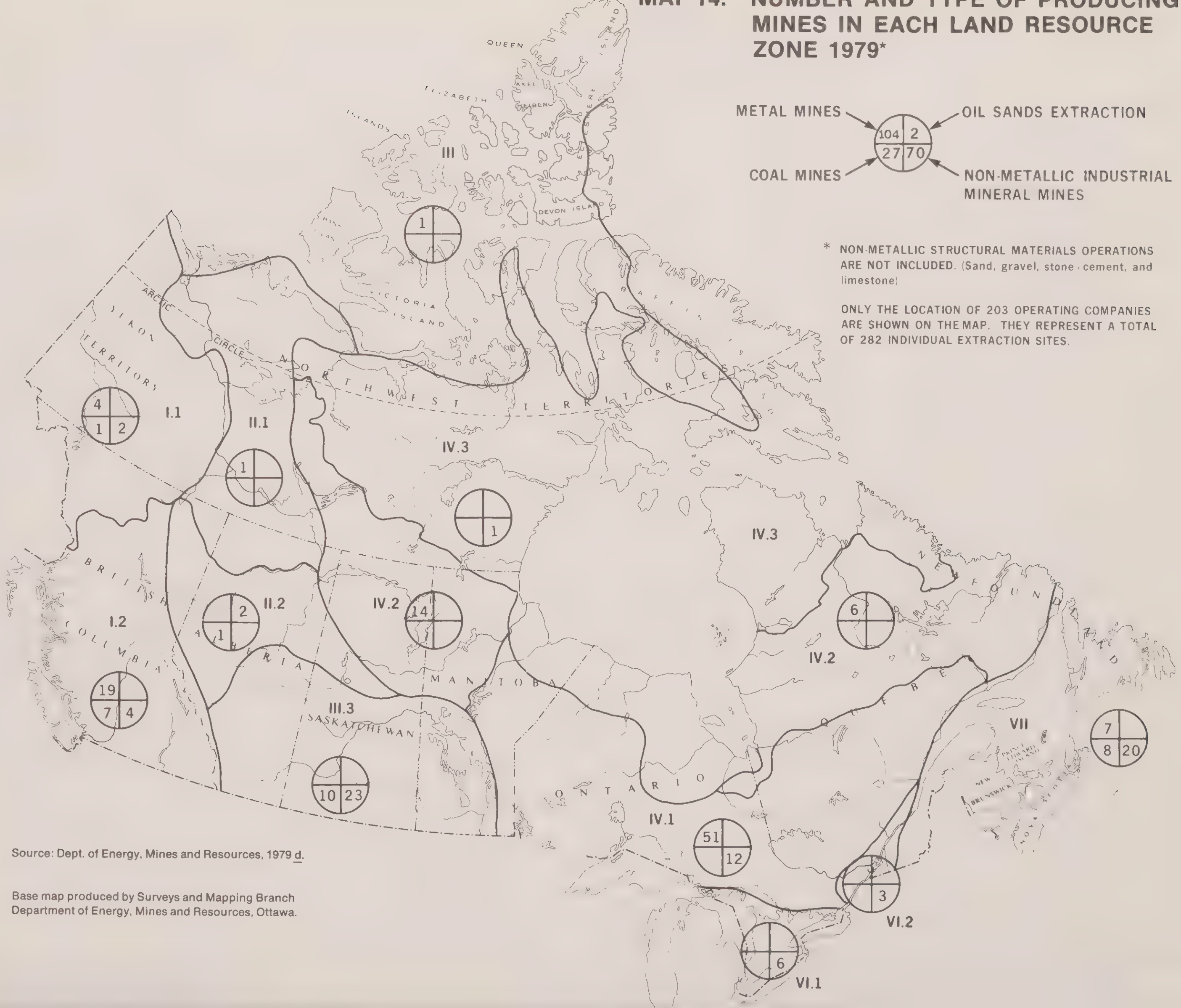


* NON-METALLIC STRUCTURAL MATERIALS OPERATIONS ARE NOT INCLUDED (Sand, gravel, stone, cement and limestone)

Sources: Annis et al., 1976 and Dept. of Energy, Mines and Resources, 1980 a.

Base map produced by Surveys and Mapping Branch. Department of Energy, Mines and Resources, Ottawa.

MAP 14. NUMBER AND TYPE OF PRODUCING MINES IN EACH LAND RESOURCE ZONE 1979*



* NON-METALLIC STRUCTURAL MATERIALS OPERATIONS ARE NOT INCLUDED. (Sand, gravel, stone, cement, and limestone)

ONLY THE LOCATION OF 203 OPERATING COMPANIES ARE SHOWN ON THE MAP. THEY REPRESENT A TOTAL OF 282 INDIVIDUAL EXTRACTION SITES.

Source: Dept. of Energy, Mines and Resources, 1979 d.

Base map produced by Surveys and Mapping Branch
Department of Energy, Mines and Resources, Ottawa.

shipping costs are lower, due to established infrastructure.

The total requirements for new mines has been adjusted downward to account for the polymetallic nature of many deposits containing copper, lead, zinc, or molybdenum. For example:

"A medium-sized (10-50 million tons of ore) zinc mine representing a typical tonnage of ultimate zinc reserves might also produce a significant tonnage of lead as a co-product; all new zinc mines required in, say, the 1991-95 period might satisfy a considerable portion of the total lead requirements in that period." (Dep. Energy Mines and Resources, 1975).

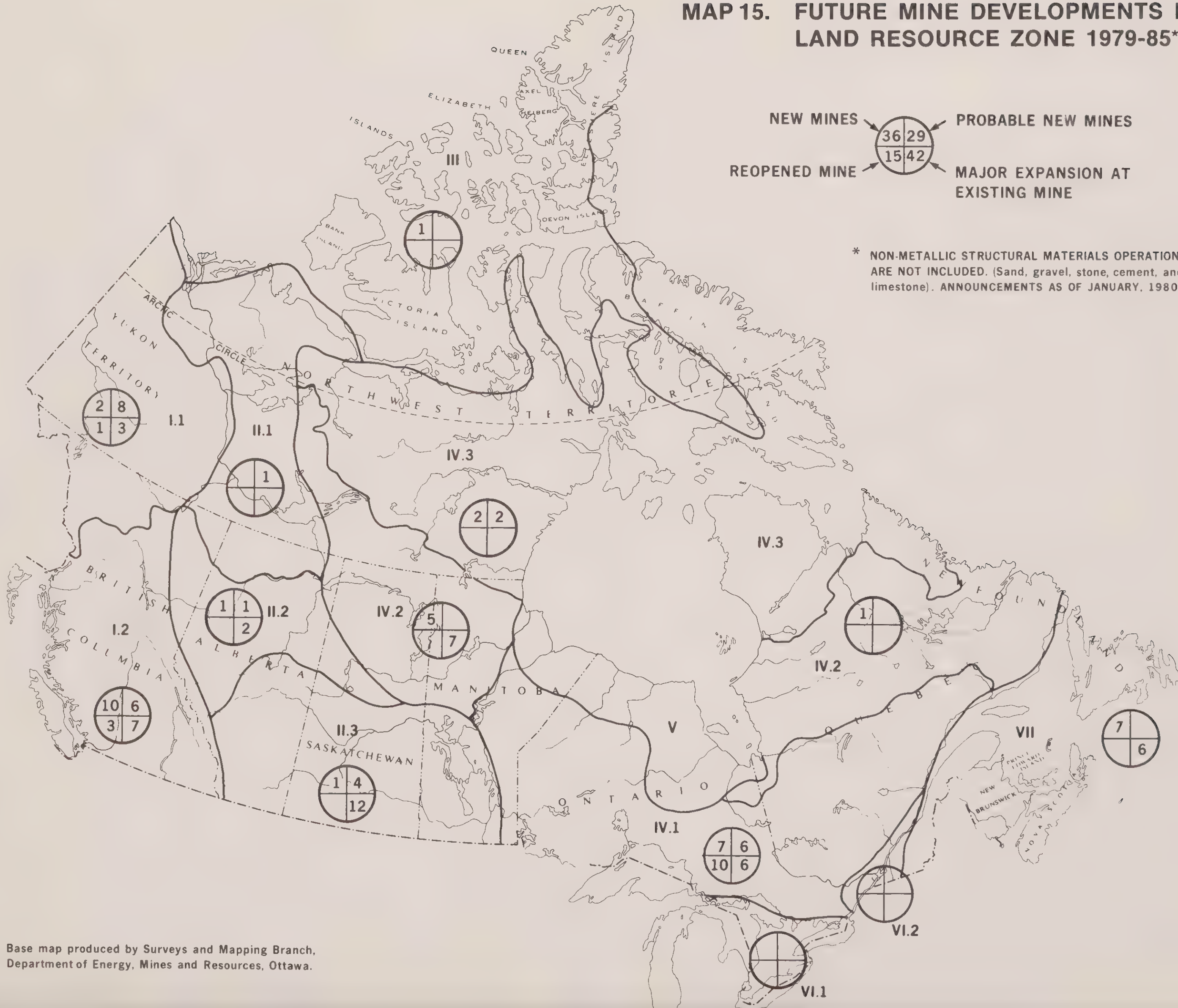
In addition, other by-product metal production associated with copper, lead, zinc, and molybdenum would have to be accounted for in order to provide for an accurate estimate of future mine requirements. In 1979, the Mining Association of Canada (Western Miner, 1979) forecast that at least 280 new mines (an average 13 mines a year) would be required by the year 2000, just to keep up Canada's current share of the world's market. This included, all metallic and non-metallic commodities, with the exception of construction materials.

TABLE 19. FUTURE MINE DEVELOPMENTS 1979-85
Summary of new, reopening, and potential mines, and major expansion projects across Canada, as of January 1, 1980

	New Mines	Reopened Mines	Major Expansion	Potential New Mines	Total
British Columbia	10	4	7	7	28
Alberta	2		7	5	14
Saskatchewan	4		8		12
Manitoba			4		5
Ontario	1	3	4	2	10
Quebec	7	7	7	4	25
New Brunswick	3		1		4
Nova Scotia	3				3
Newfoundland Labrador	1				1
Yukon/N.W.T.	4		4	11	20
TOTAL	36	16	42	29	122

Sources: Pabst, 1979a and 1980; Western Miner, 1979 and 1980; Roberts, 1981.

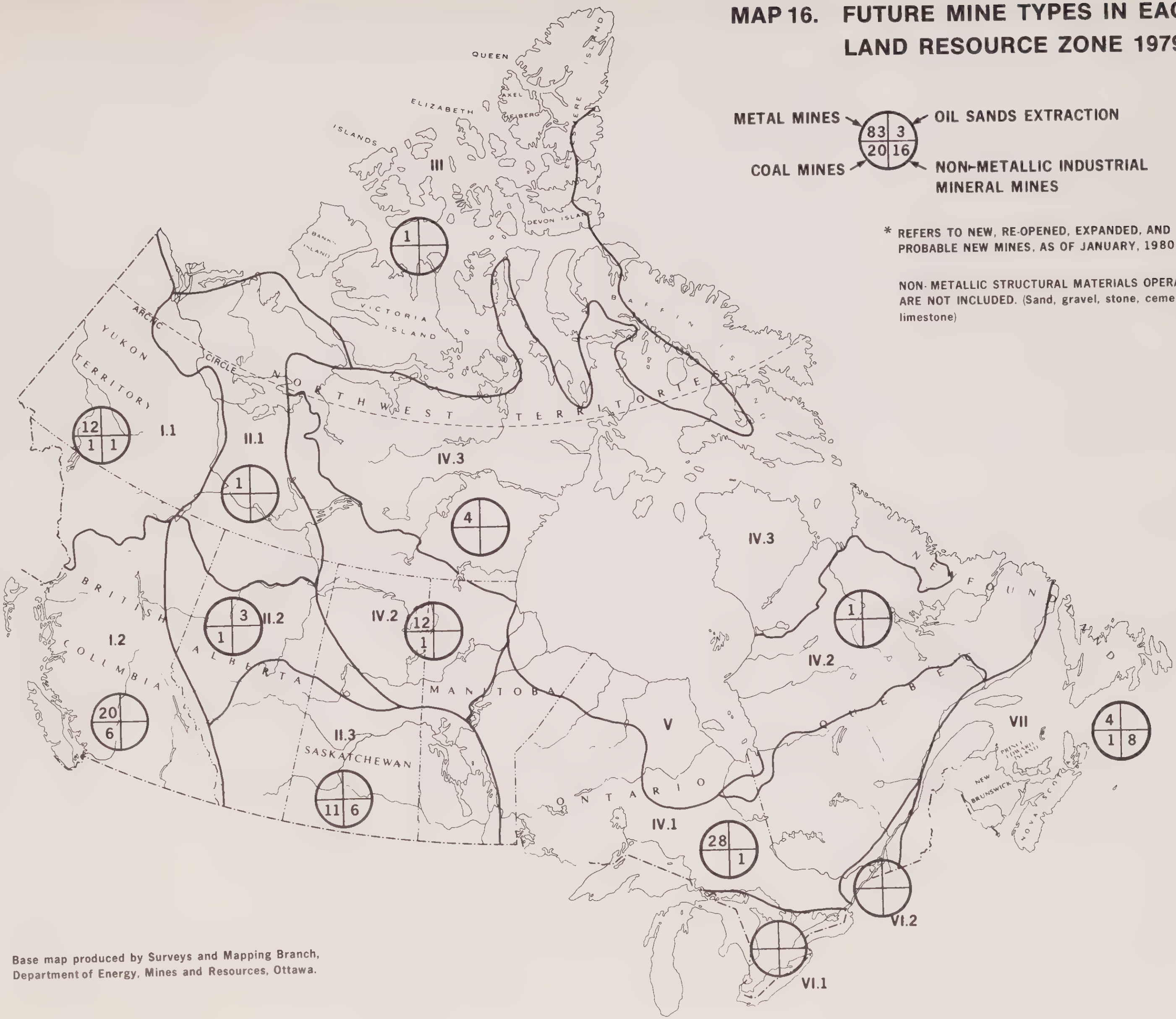
MAP 15. FUTURE MINE DEVELOPMENTS IN EACH LAND RESOURCE ZONE 1979-85*



* NON-METALLIC STRUCTURAL MATERIALS OPERATIONS ARE NOT INCLUDED. (Sand, gravel, stone, cement, and limestone). ANNOUNCEMENTS AS OF JANUARY, 1980.

Base map produced by Surveys and Mapping Branch, Department of Energy, Mines and Resources, Ottawa.

MAP 16. FUTURE MINE TYPES IN EACH LAND RESOURCE ZONE 1979-85*



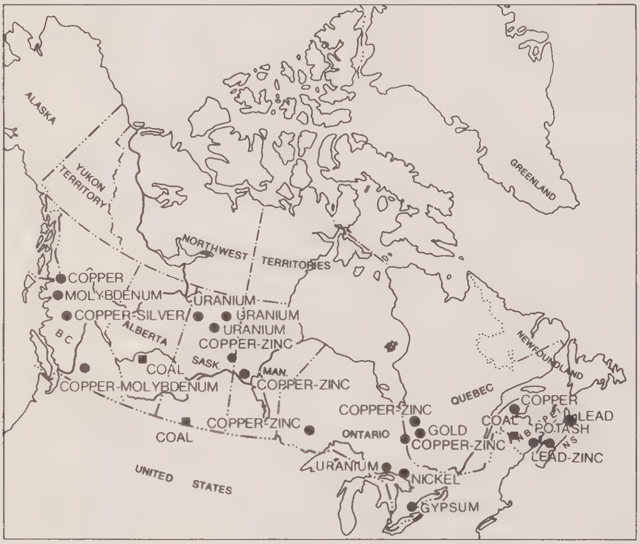
* REFERS TO NEW, RE-OPENED, EXPANDED, AND PROBABLE NEW MINES, AS OF JANUARY, 1980.

NON-METALLIC STRUCTURAL MATERIALS OPERATIONS ARE NOT INCLUDED. (Sand, gravel, stone, cement, and limestone)

Base map produced by Surveys and Mapping Branch, Department of Energy, Mines and Resources, Ottawa.

MAP 17. MINES BEING DEVELOPED FOR PRODUCTION: 1978, 1979

1978



1979

Reproduced from: Dept. of Energy, Mines and Resources, 1979 d.

A period of accelerated growth in mine development in some sectors of the industry can be expected in the first half of the 1980's (Table 19). Overall the mineral market was depressed between 1973 and 1979. During the 1979 to 1985 period covered in this table, 64 commitments have been made for new mines; major expansions at existing mines; and the reopening of old mines, in addition to 19 new mine proposals. The distribution of these mine developments, according to land resource zones, are mapped by type of development (Map 15), and by type of mine (Map 16). Map 17 identifies the location and mineral commodities being produced from those new mines that were being developed for production as of January, 1978 and 1979 (an increase from 10 to 22).

Twenty-two of the 83 metal-mine developments are associated with increased gold production, half of which are new mines, the remainder are expansions of existing mines or reopenings of older ones. The rapid rise in the price of gold from a low of $200.00 (US) during 1978 to in excess of $600.00 (US) in 1980 has led to an air of "gold rush fever". Mining ventures which were previously uneconomic have now become profitable, especially with the added advantage of the depressed Canadian dollar. The heaviest concentration is in Quebec (11), followed by Ontario, Yukon, and British Columbia. In excess of 6,400 kilometres of claims and leases were in effect by 1980 in the Yukon, the majority of which are concentrated in the Klondike, Kluane, Clear Creek, Mayo, and Leduc river valleys. However, much of the recent staking is peripheral to the major established placer areas. In the Yukon Territory, with the exception of two, proposed underground mines, the major emphasis is on a large number of placer mines and smaller individual claims. By January, 1980, there were 106 placer operations producing in the Yukon, 94 of them in the Klondike and Sixty Mile river regions (*see* Map 4). In addition, it is likely that 20 to 30 small underground gold-mine proposals are being considered at this time for development in the next five years across Canada. Several involve the reworking of mine tailings at abandoned sites (primarily in Ontario and Quebec).

More than half of the new metal-mine developments are associated with the increased production of copper, molybdenum, lead, and zinc. Eleven are associated with potential new mines in the Yukon and Northwest territories (includes a uranium-mine proposal), and in most cases, there would be by-product production of gold and silver. Increased mining development in British Columbia is centred on new, expanded, or reopened copper, copper/molybdenum,

copper/silver, or copper/gold mines, (17 in all). In the traditional northern mining regions of the Canadian Shield, the new mines are primarily copper/zinc producers (with by-product lead, silver, or gold) and major expansions are associated with copper, lead, zinc, and nickel.

Associated with the beginning of production in Nova Scotia of two new lead and lead/zinc mines, is the increased diversification of mineral commodities produced in the Appalachian region in general. A new tungsten mine is being developed in New Brunswick, the only one apart from Tungsten in the N.W.T.

NON-METALLIC MINERALS

Future development of mines for industrial minerals and fertilizers indicate that, over the period 1979 to 1985, commitments have been made for three new mines, nine major expansions at existing mines, and four new mine proposals (*see* Maps 15 and 16).

For the first time, potash will be mined outside Saskatchewan when two new (potash/salt) developments are completed northeast of St. Johns, New Brunswick (*see* Map 17). In addition, six potash mines in Saskatchewan are expanding production, and it is expected that this expansion in the 1980's will have to be rapid in order to compete with major overseas competitors, Russia and East Germany. An annual growth rate of 4.3 percent for the industry is anticipated (Dep. Energy, Mines and Resources, 1980). A new salt mine is being developed on the Magdalen Islands.

With the exception of the potash and salt developments, commitments to other new developments have been few, and confined to the proposal level only. Three possible asbestos mines are currently being investigated in Quebec (Amos and Chibougamau regions in the northwest, and Asbestos Hill near Ungava Bay, *see* Map 1) and one at Deese Lake in northwestern British Columbia. However, asbestos mine development is likely to be retarded in the 1980's due not only to the uncertainties surrounding the future role of the provincial government in Quebec, but also to relatively poor construction activity, and restrictive environmental legislation on its use in the two principal markets, the United States and the European Common Market (Dep. Energy, Mines and Resources, 1980). Much of the potential increase in production may be handled by expansions at existing mines. Hence, annual growth rates are likely to remain low, between 1.5 and 2 percent.

Individual forecasts on future pit and quarry developments for the remainder of the industrial minerals and construction materials was unavailable. However, due to their heavy reliance on the construction industry, the general location of construction materials sites near the most-populated areas of Canada is unlikely to change. Depletion of existing resources and lack of access to aggregates in certain areas may cause problems in the future. Since the majority of aggregates are transported by truck, distance is usually restricted to less than 40 kilometres. In the near future in certain regions — for example the Toronto and Vancouver metropolitan regions — alternate modes of transportation or even mining of aggregates may have to be considered in order to secure supplies at competitive prices. Some provinces are already investigating the transport of aggregates by rail and barge, and in some cases the potential of mining crushed stone underground within the boundaries of urban centres. In the past few years, demand has stabilized at 17 tonnes per capita for all of Canada; however, the rapid development of some regional economies, particularly those centred on the three western most provinces are likely to see a significant increase in sand, gravel, and crushed-stone operations.

The United States Bureau of Mines (1976) forecast an annual growth rate of 2.8 percent for sand and gravel, and 3.2 percent for crushed stone between 1973 and 2000. Because Canada's per capita demand for these materials is similar to that of the United States these figures can be used for the purpose of comparison. Similar annual growth rates in Canada would result in an increase in sand and gravel production from 327 to 568 million tonnes between 1980 and 2000. The increase in crushed stone would be from 103 to 198 million tonnes for the same period (*see* Table 8). In fact, Canada's annual growth rate has been somewhat higher. The United States Bureau of Mines indicates that future annual production rates outside the United States could be as high as 3.5 percent for sand and gravel, and 4.2 percent for crushed stone. Based on the United States growth rate, and minimum estimate of 2.98 billion tonnes of crushed stone and 8.85 billion tonnes of sand and gravel will be required in Canada between 1980 and 2000.

ENERGY-RELATED MINERALS

Oil Sands

Of the two existing oil-sands operations, only Suncor has announced expansion plans to increase its capacity 15,000 barrels/day. However, a third oil-sands project (Alsands) is now being considered at Fort McMurray that would provide an additional

125,000 barrels/day after 1985, affecting an area similar to that of the Syncrude plant.

Although *in situ* projects do not require large areas for extraction and storage of wastes typical of surface mining operations:

"...the wells will be closely spaced, less than 121 m apart, surface clearing of comparable areas will be required. The lands will be occupied by in situ wells for approximately seven years. Lag times between overburden stripping and reforestation (reclamation) is estimated to take ten years." (Simpson-Lewis et al., 1979).

Under the circumstances, should *in situ* methods be added in the future to existing surface-mining methods in the Athabasca deposits there would be increased potential for more widespread regional impacts. Support requirements associated with both types of oil-sands developments (surface and *in situ*) such as roads, power lines, and community developments will require additional surface disturbances, as well as pipeline and transmission systems.

Coal

Domestic coal production in Canada is expected to increase dramatically from 33.6 to 102 million tonnes annually between 1979 and 2000 (Table 20). Potential annual demand for Canadian coal has been forecast as high as 163 million tonnes by the year 2000 (Bielenstein *et al.*, 1979). The greatest increases (up to 350 percent) in production are expected in Saskatchewan, Alberta and British Columbia (LRZ's I.2 and II.3). By the year 2000, these three provinces will increase thermal and metallurgical coal production to 57 and 20 million tonnes respectively. It is anticipated that a further 7 million tonnes will be converted to liquid fuel in Alberta by the year 2000. All but 9.3 million tonnes will be extracted by surface or open-pit methods (*see* Tables 16 and 20). During the same time-frame coal production in eastern Canada is expected to reach 11 million tonnes annually of which 9 million tonnes will be thermal coal (6.1 million tonnes by surface techniques).

In Alberta, a much expanded coal program has been projected to potential gasification and a synthetic chemical industry. Demand for sub-bituminous coal for thermal power generation is projected to rise from 6.6 million tons in 1945 to 87.8 million tons in 2004 (Hermans and Goettel, 1980). The Energy Resources Conservation Board also predicts an annual rise of 43.8 million tons of coal for gasification by 2004, and coal feed stocks for a proposed petrochemical industry are estimated at 12.2 million tons annually by 2004. Annual demand is expected to rise from 6.6 million tons in 1973 to 143 million tons in 2004.

In order to meet this three-fold increase in coal production, the number and size of individual surface-mine operations will increase significantly, particularly strip mines in the Interior Plains region (LRZ II.3). The basic methods now in use are unlikely to change significantly, but larger, more-automated equipment will be used to extract and transport the increased volume of overburden and coal.

Although many coal properties are known to have considerable potential for production within the next decade, particularly in British Columbia and Alberta, not all have passed beyond the initial proposal stage. Table 21 lists 14 of the more-significant proposals for new mines or major expansions to existing mines, which would account for almost 65 percent of the estimated production by the year 2000. In British Columbia, the major focus of attention are the coal fields in the northwest Peace River, and southeast Kootenay regions (*see* Map 9, nos. 5, 1, and 3). In the southeast region, three existing mines (Kaiser, Fording, and Byron Creek) have proposed expanding production gradually and a new mine at Line Creek has progressed beyond the first development stage. Two additional deposits, one at Elk River and the other at Sage Creek may be considered. In the northeast Peace River (*see* Map 9, No. 3) the economic development and long-term practicality of the coal block depends on three significant factors: the technical and economic feasibility of mining various coal deposits; the procurement of long-term contracts for the sale of the coal; and the construction of costly infrastructure — especially a new railway (George, 1980). However, recent interest in long-term contract commitments between Japan and Canada may provide the catalyst to spur considerable development. The first deposits likely to be developed are the Sukunka and Quintette. An additional five sites (Bullmoose, Saxon, Montman, Carbon Creek, and Bowron River) could progress beyond the initial development stages should the export market be strong enough. Although production has been indicated as 6.5 million tonnes (*see* Table 2l) for the Quintette and Sukunka properties potential production has been estimated as high as 9.7 million tonnes (Roberts, 1981).

The last major development proposal is the BC Hydro Hat Creek integrated mine and thermal plant in south central British Columbia. Its future is dependant on whether or not it can meet environmental and economic criteria.

The greatest increase in mining activity (in terms of tonnes produced) is likely to occur in the Interior Plains (LRZ II.3) of Alberta and Saskatchewan where 12 new or expanded coal mines have been proposed to date. New developments in Alberta include four large strip mines, of which the Genessee, Shearness, and Keephills will provide coal for thermal plants, and the one at Forestburg, coal liquefaction. Two smaller underground mines, the Kipp property near Lethbridge, and Judy Creek on the eastern slopes of the Swan Hills northwest of Edmonton, are in the test-pit stages. The latter is expected to supply thermal coal to the proposed Esso Cold Lake Heavy Oil plant. Significant expansions of existing operations are planned for the Highvale and Vesta mines (*see* Table 21) to supply thermal plants. With the exception of the Judy Creek mine, all of the mines are located in the humid agricultural plains (*see* Map 9, No. 9). Few proposals for the extraction of bituminous coal from the mountains and foothills of Alberta are imminent due to the zoning restrictions introduced in Alberta policies for coal development and resource management of the Eastern

TABLE 20. ESTIMATED FUTURE COAL PRODUCTION 1980 - 2000
(By Province and Type)

Province	End Use	1980	1990	2000
			(Tonnes x 10^6)	
British Columbia	Metallurgical	9.6	11.6	14.6
	Thermal	0.8	1.0	13.7
	TOTAL	10.4	12.6	28.3
Alberta	Metallurgical	3.0	3.7	5.3
	Thermal	11.2	22.9	34.6
	Liquefaction	0	1.0	7.0
	TOTAL	14.2	27.6	46.9
Saskatchewan	Thermal	6.5	9.2	16.0
Ontario	Thermal	0	2.0	4.7
New Brunswick	Thermal	0.5	1.3	1.3
Nova Scotia	Metallurgical	1.5	2.0	2.2
	Thermal	1.4	2.54	2.9
	TOTAL	2.9	4.5	5.1
Yukon	Thermal	.01	.01	.01
CANADA	TOTAL	34.5	57.2	102.3

Sources: Dep. Energy, Mines and Resources Canada, 1978; Draper and Dwyer, 1979; Labuda _et al._, 1979; Alysworth, 1980; Alberta Environment, 1980.

TABLE 21. PROPOSED, NEW OR EXPANDED COAL MINES

	Coal Region No. (Map 4)	Coal Type	Mine Type	Estimated Production (tonnes X 10^6)			End Use
				1980	1990	2000	
British Columbia							
B.C. Hydro - Hat Creek	2	Sub-bit	O.P.	0	0	10.7	Thermal-Hydro
B.P. Canada Ltd., - Sunkunka	3	Bit	U.G.	0	1.0	2.0	Export
Denison Mines Ltd., - Quintette	3	Bit	U.G.	0	1.0	2.0	Export
Alberta							
Sheerness Mines; Sheerness	9	Sub-bit	S	0	2.5	6.5	Thermal-Hydro
Genessee Mine, Genessee	9	Sub-bit	S	0	2.5	6.5	Thermal-Hydro
Keephills Mine, Wabamun	9	Sub-bit	S	-	2.5	6.5	Thermal-Hydro
Forrestburg Coal Liquification	9	Sub-bit	S	0	1.0	7.0	Thermal-Hydro
Highvale Mine, Seba Beach (E)	9	Sub-bit	S	5.8	8.0	18.3	Thermal-Hydro
Vesta Mine, Halkirk (E)	9	Sub-bit	S	0.8	1.3	1.4	Thermal-Hydro
Saskatchewan							
S.P.C. Cornach Mine (2nd phase) (E)	13	Lig	S	0	0	3.4	Thermal-Hydro
Mananalta, Bienfait Mine (E)	13	Lig	S	0	0	3.4	Thermal-Hydro
	13	Lig	S	0.5	2.3	5.1	Thermal-Hydro and export to Ontario
Ontario							
Onakawana Devl. Corp.	14	Lig	S	0	2.0	4.7	Thermal-Hydro
James Bay Mine							
Nova Scotia							
Devco - Donkin Mine	17	Bit	U.G.	0	0.3	0.4	Thermal-Hydro
Novaco - Sydney Area	17	Bit	S	0.07	0.08	0.08	Thermal-Hydro

E - Expansion

Source: Blakeman, 1980.

Slopes (Alberta, Dep. Energy and Natural Resources, 1976 and 1977). At the existing mines in Alberta, only the Rosalyn and Whitewood mines are expected to close operations during the 1990's; the remainder are expected to continue, some with gradual increases in production, depending on market conditions.

Coal mining in Saskatchewan was confined to the Estevan-Bienfait region, until 1979, then the first strip mine opened at Cornach in the Willow Bunch coal field (*see* Map 9, No. 12) to provide coal for the new East Poplar generating station. This is the first of a proposed two-phase development that is projected to produce an estimated 6.8 million tonnes by the year 2000. Of the five existing mines in the Estevan-Bienfait region (*see* Map 9, No. 13), production is expected to decline at three (Utility, Boundary Dam, and Souris Valley mines) during the next two decades and remain the same at the Klimax mine. Only the Bienfait mine (Manitoba and Saskatchewan Coal Co.) is expected to expand its production significantly in the next decade (*see* Table 21).

Considerably less development is projected in the coal fields of eastern Canada. In Ontario (LRZ V), proposals to develop a strip mine to extract lignite for use in a James Bay Generating Station (*see* Map 9, No. 14) are still under investigation. Increased production in the coalfields of the Appalachian Region (LRZ VII) are expected to be less than two million tonnes during the next two decades. The Minto/Chipman operations of New Brunswick Coal Ltd. (*see* Map 9, No. 17) are the only ones expected to more than double existing production rates. The remaining seven mines are expected to remain at the same or slightly lower production levels. Only the Thorburn Mine at Stellarton is expected to close down after 1990. To date, new mine proposals have been confined to the coal fields on Cape Breton Island. One is a proposed underground mine at Donkin by Devco and three small strip mines in the Sydney area by Novaco.

Coal production in the Yukon (LRZ I.1) is limited to the Tantalus Butte mine which supplies 7,700 tonnes of thermal coal to the Cypress Anvil Mine for the drying of zinc concentrate. Known coal occurrences in both the Yukon and Northwest territories have not been thoroughly explored or economically evaluated. Therefore, data pertaining to the resources contained in known deposits in the Yukon and Northwest territories were not included in the figures presented (*see* Table 16). Only one coal deposit (Bonnet Plume) may be developed before 1990, subject to favourable prices, access, infrastructure, and investment climate.

There has been a significant resurgence of interest in the use of thermal and metallurgical coal for both foreign and domestic markets. The return to coal as an alternate source of energy has had a more immediate effect on the thermal coal sector. For example, in 1979, the first major interprovincial shipments (2 million tonnes) of thermal coal were started between mines in British Columbia and Alberta, to Ontario Hydro's Nanticoke thermal generating station on Lake Erie (Aylsworth, 1980).

Uranium

New mine developments within the next five years have been proposed in the provinces of Newfoundland, Ontario, Saskatchewan, and British Columbia. In eastern Labrador, at Makkovick near the coast (LRZ IV.2), there is a proposal by British Newfoundland Exploration Ltd. to develop the Kitts and Michelin deposits initially by open pit, beginning in 1982. In Ontario (LRZ IV.1), Rare Earth Resources Ltd. and Esso Minerals proposed to exploit three new deposits in the Bancroft area beginning in 1980. The ore will be custom-milled at Madawaska Mines Ltd. Mine expansions at Denison Mines, Rio Algom, and its affiliate Preston Mines Ltd. in the Elliot Lake region are all projected for 1982-83. In Saskatchewan (LRZ IV.2), the Amok Mine at Cluff Lake started production in 1980, and proposals to begin mining the Key Lake deposits by 1983 have been submitted. A similar proposal has been submitted to develop the Midwest Lake deposits which are 24 km west of the existing Rabbit Lake Mine. The Kitts-Michelin, Key Lake, and Midwest Lake mine proposals are all in the public inquiry/environmental assessment approval process at this time. Similarly, in British Columbia the proposed development of two uranium deposits (the Blizzard and Birch Island in south-central B.C.) have been delayed by the provincial inquiry (Bates Commission) into uranium exploration and production activity established in 1979. This was followed by the announcement of the British Columbia government early in 1980 that there would be a moratorium placed on any further uranium exploration and development proposals within the province.

The Uranium Resource Appraisal Group (Dep. Energy, Mines and Resources, 1979*c*) taking into account the above proposed developments, known mineable resources, and assuming adequate infrastructure, financing and markets, estimated that production can be expected to increase from 6,900 tonnes in 1979 to 13,500 tonnes in 1984 and to 15,500 tonnes by 1990. It points out that this level of production could not be maintained for long without additional discoveries.

In areas in Canada favourable for the occurrence of uranium deposits (*see* Map 10), exploration for uranium has increased dramatically since 1973, when the price/kg rose from less than $20 to greater than $125 in 1978 (in current dollars). Active exploration for uranium occurred in all provinces and territories with the exception of P.E.I. The largest expenditures occurred in Saskatchewan accounting for 48 percent of the total, with the Northwest Territories accounting for some 19 percent of the total, and with Quebec and British Columbia ranking third and fourth with approximately 8 percent of the total. Early results of this increased exploration activity have already been identified in the proposed developments mentioned earlier. Significant results of 1978-79 exploration activity were discoveries of further deposits in northern Saskatchewan in the Rabbit Lake area (McLean Lake and April Bay deposits) and in the Shultz Lake Area, west-northwest of Baker Lake, N.W.T. Other areas of potential have been identified near Tombstone Mountain in the Yukon, the Lake George area of New Brunswick, and Lake Gayot, north of La Grande Rivière in the James Bay Area of northwestern Quebec (Williams, 1980). Exploration activity is likely to continue to focus on these areas in the future, however, mine developments in the next five years will probably continue to be in Saskatchewan and Ontario where infrastructure exists.

The projected future domestic requirements for uranium have been forecast by the Uranium Resource Appraisal Group in 1978 as follows:

"Of the total recoverable 'adjusted reserve' summed for all Canadian uranium producers marketing uranium, about 23.5% will be required to provide the 30-year fuelling requirements of 69,000 tonnes U for the 15,935 megawatts of nuclear power capacity expected to be operating in Canada by 1989. Moreover, to conform to federal policy, domestic utilities are required to have contracted for 31,500 tonnes to provide 15-year fuelling requirements for the 14,455 megawatts of nuclear generating capacity now operating or committed for operation by 1989." (Dep. Energy, Mines and Resources, 1979c).[12]

[12] The domestic allocation for each producer was determined from their measured, indicated, and inferred resources mineable at uramium prices of up to $175/kg U, with weighting factors of 1.0, 0.8, and 0.7 respectively (the factors for the last two categories were chosen to reflect a lower degree of reliability than that for the measured category). Individual mill-recovery factors were then applied to the weighted tonnages for each category; the sum of the weighted tonnages in the three categories adjusted in this manner is termed the recoverable *adjusted reserve*, for the purpose of the domestic allocation procedure.

The same forecast estimates that Canadian producers and potential producers will still have more than half of their recoverable adjusted reserve uncommitted to meet future export or domestic needs.

LAND RESOURCE ZONES AND MINING

A comparison is made between the number of current operating companies, known non-producing mineral deposits, and proposals for new mine developments (new, expanded, reopened, and proposed), and the other major land uses in each Land Resource Zone (Table 22). The figures confirm that there has not been any major alteration in the overall distribution of ***metallic mines*** among the various land resource zones. As expected, the greatest concentration of currently operating metallic mines occurs in the Southern Boreal Shield (49 percent), followed by the Central Subarctic Shield (19 percent) and the Southern Cordilleran Zone (19 percent). Significantly, over 85 percent of the metallic mines are located in the most productive forest lands of Canada (*see* Map 12).

The number of new metallic deposits discovered in each Land Resource Zone as a percentage of all new deposits in Canada has remained relatively constant with the exception of a slight increase in activity in the Appalachian Zone and Southern Boreal Shield. But, there has been a significant increase in the level of exploration and development in the past two years. Variations within each zone are evident due to the vast size of some zones and the mineral commodity being pursued.

There is now some evidence of a shift in the future distribution pattern of metallic mines away from the heavy concentration in Ontario and Quebec, to the outer extremities of the country. Almost a quarter of the new metallic mine developments (new, expanded, and reopened) are located in the southern Cordilleran Zone, the majority of which involve copper production (often associated with molybednum, gold, and silver by-products). A high percentage will be open-pit operations, adding to the concerns for a wide range of land use activities in the environmentally sensitive zone. In addition, there has been an increased diversification of metal mining in the Appalachian Zone, particularly with the return of metal mining to Nova Scotia.

Another aspect of the gradual shift in metallic mine development is the movement northward. For the first time there are mines in the frozen Arctic Archipelago and the Arctic Shield, and the prospect of several more in the 1980's. Similarly, in the Northern Cordill-

TABLE 22. COMPARISON OF CURRENT AND FUTURE MINING ACTIVITIES WITH OTHER LAND USES: By Land Resource Zone

LAND RESOURCE ZONES / LAND USE ACTIVITIES		- Field Crops and Grazing	- Ranching and Grazing	- Horticultural	Agriculture - Mixed Farming and Forage	Forestry	Fisheries	Urban Settlement	Energy - Oil and Gas	Wildlife - Wilderness Preservation	Hunting and Trapping	Tourism - Scenic	Outdoor Recreation	Native Peoples (rights/claims)	Metallic[a]: Non-producing Deposits 1975	Metallic[a]: Non-producing Deposits 1980	Metallic[a]: Operating Companies, 1979	Metallic[a] 1979-85: New Mines	Metallic[a] 1979-85: Expansion of Existing Mine	Metallic[a] 1979-85: Re-opened Mine	Metallic[a] 1979-85: Probable New Mine	Non-metallic[b]: Operating Companies: 1979	Non-metallic[b] 1979-85: New Mines	Non-metallic[b] 1979-85: Expansion of Existing Mine	Non-metallic[b] 1979-85: Re-opened Mine	Non-metallic[b] 1979-85: Probable New Mine	Energy[c]: Operating Companies: 1979	Energy[c] 1979-85: New Mines	Energy[c] 1979-85: Expansion of Existing Mine	Energy[c] 1979-85: Re-opened Mine	Energy[c] 1979-85: Probable New Mine
I.1	Northern Cordilleran						X			XX	XX	X		XX	46	107	4	2	2	1	7	2		1			1				
I.2	Southern Cordilleran		XX	XX	X	XX	XX	X		XX	X	XX	XX	XX	72	207	19	9	5	3	3	4					7	1	2		3
II.1	Northern Interior Plains						X		XX	X	XX			XX	1	2	1				1										
II.2	Central Interior Plains (Peace, Athabasca)	XX			X	X	X		XX	X	X	X	XX	X													1	1*	2*		
II.3	Southern Interior Plains (Prairies)	XX	XX					X	XX													23		6			10	1	6		4
III.	Arctic Archipelago									XX				XX	2	4	1	1													
IV.1	Southern Boreal Shield				X	XX	XX			X	XX	XX	XX	X	197	625	51	7	5	10	6	12		1							
IV.2	Central Subarctic Shield					X	XX			XX	XX			XX	81	184	20	6	7												
IV.3	Arctic Shield									XX	XX			XX	20	31	0	2			2										
V.	Hudson Bay Lowland									X																					
VI.1	Lower Great Lakes			XX	XX			XX				XX	XX									6									
VI.2	Central St. Lawrence Lowlands			XX	XX			XX				XX	XX		12	22						3						1			
VII.	Appalachian			X	XX	XX	XX	X		X	X	XX	XX		52	163	7	3	1			20	2	6			8				

(a) Total includes uranium mines, discussed in wider energy section in text. Includes two probable new mines in LRZ I.2 ; one new and two reopened in LRZ IV.1 (Ontario); five new and one expanded in LRZ IV.2; all in Saskatchewan, with the exception of one in Labrador.

(b) Includes salt, potash gypsum, sodium sulphate, barite, napheline syenite. Excludes structural materials.

(c) Includes coal and oil sands, oil sands are indicated by asterisk.

X - Significant XX - Major

McIntyre Coal Mine, Grande Cache, Alberta
NFB — Phototheque — ONF, George Hunter

eran Zone dominated by the Yukon Territory, considerable growth is projected in the next decade, that will see a potential two- to three-fold increase in the total number of mines. Coupled with this is the dramatic increase in placer gold mining which is under considerable pressure to expand beyond its traditional areas of activity. Overall, the extreme fragility and slow ability of the northern environment to recover, combined with concerns over wildlife and wilderness preservation, native rights and claims, fisheries, and hunting and trapping may limit the rate of further development. Despite these signs of a change in direction of new mine development the Southern Boreal Shield continues to be the largest single centre of metallic mining activity.

It is unlikely that any significant changes will take place in the future distribution pattern of the ***non-metallic*** sector of the mining industry. Over 80 percent of the industrial and fertilizer sectors of the industry are located in the Southern Interior Plains, St. Lawrence Lowlands, and Appalachian zones. Both sectors are characterized by a high degree of geographic concentration according to the commodity produced. Due to the emphasis on the expansion of capacity at existing facilities it is unlikely that there will be any significant increase in the demand for further land resources in the next five years.

Only the expansion of the ***construction materials*** sector will continue to grow and affect significant new areas of land in the settled southern Land Resource zones (LRZ's I.2, II.3, VI.1, VI.2, and XII) thus continuing to contribute to land use pressures and conflicts in these highly utilized areas.

Of all the sectors of the mining industry, ***energy*** development has the potential to directly affect the most land as well as significantly influence many new areas in the Southern Cordilleran and Southern Interior Plains and, to a lesser extent, the Appalachian Zone. Almost a third of all the new mine developments identified in the 1979 to 1985 period are associated with the energy sector. The major focus of new uranium developments is taking place in the northern Saskatchewan sector of the Subarctic Shield where it is forming the basis of a new major mining region. Much of the future development of uranium mines will continue to be confined to northern Saskatchewan and central Ontario, due to the moratorium on the development of uranium mines in other promising areas (British

Columbia, Newfoundland/Labrador, and the Northwest Territories).

Should the predicted three-fold growth in demand for coal take place by the year 2000, then the greatest impact will be felt in the Southern Cordilleran and Southern Interior Plains (dominated by open-pit and surface strip mining). A major new coal mining region is being developed in the northeast coal block of British Columbia which will require considerable infrastructure development. In terms of area disturbed, the largest expansion will take place in the humid agricultural plains of Alberta. In the Saskatchewan plains, the first mine in the Willowbunch coal field is now operational and it is expected that the Estevan-Bienfait field will gradually decline and close by the year 2000. Coal mining in the Appalachian will remain confined to existing fields.

The major concerns over development will be the effects on forestry, wildlife, recreation, tourism, and fisheries in the Cordilleran Zone, and on agriculture and groundwater supplies in the Interior Plains. Concerns in the Appalachian zone will be related to surface disturbance and acidic drainage as they affect the fishing, tourism, and recreation industries.

FUTURE OUTLOOK AND CONSTRAINTS

There are certain general factors which may limit the future development of mines. Not all the "developable" mineral deposits previously identified in this report are likely to escape the various constraints imposed by global and internal economic conditions, geographic and infrastructure concerns, technological limitations, and regulatory requirements. Thus, some understanding of the role that these constraints can play in the growth and viability of the mining industry is necessary. Important to this discussion is the current economic significance of mining to Canada's economy and what the future outlook of the industry appears to be in the next decade.

ECONOMIC SIGNIFICANCE

In 1980, the value of mineral production reached an all-time high of $32.7 billion, of which, petroleum and

TABLE 23. APPROXIMATE RELATIONSHIPS BETWEEN THE MINERAL INDUSTRY AND THE CANADIAN ECONOMY *

	Mining		Mineral Processing		Total	
	1974	1978	1974	1978	1974	1978
	(percentage)		(percentage)		(percentage)	
GNP	2.7	1.9	2.9	2.5	5.6	4.4
Labour Force	0.9	0.8	1.8	1.6	2.7	2.4
Wages and Salaries	1.2	1.3	2.3	2.3	3.5	3.6
Capital Expenditures	3.4	3.1	3.7	3.3	7.1	5.3
Merchandise: Exports	10.1	7.2	10.1	10.6	20.2	17.8
Merchandise: Imports	1.6	0.8	9.2	5.2	10.8	6.0

* excludes oil and gas sector

Source: Tibbo, 1981.

natural gas accounted for 56 percent. The relative importance of fossil fuels to the growth of the mineral industry and the national economy changed dramatically in the 1970's. During this decade, the production value of coal has increased from $1.6 billion to $17.5 billion. This has altered significantly the leading role that the metallic and non-metallic sectors held in the past.

The relationship between the mineral industry and the Canadian economy is indicated in Table 23. Mining and mineral processing in 1978 (excluding oil and gas) accounted for 4.4 percent of the GNP and directly employed approximately 2.4 percent of the labour force (approximately 9 percent indirectly). However, in the period between 1974 and 1978 there has been an overall decline in the contribution to GNP, capital expenditures, and value of exports and imports. Only wages and salaries have increased. The overall balance of mineral trade between Canada and the rest of the world continues to be in Canada's favor. In 1978 merchandise exports for mining and processed minerals amounted to $17.8 billion whereas imports came to only $6 billion. The mineral industry remains Canada's largest earner of foreign exchange next to the forest-product industry. In addition, it continues to be a major factor in the economic development of Canada's more northern regions and the main source of employment for many existing northern settlements. Internationally, Canada leads the world in mineral exports (non-fuel) and is the third largest producer of minerals and metals in the world after the United States and the Union of Soviet Socialist Republics. The leading Canadian mineral exports and their percentage of world markets are indicated in Table 24. Internally, mining creates new jobs, initiates and supports new transportation networks, and provides markets for Canadian-produced goods and services.

TABLE 24. CANADA'S ROLE AS A PRODUCER OF CERTAIN IMPORTANT MINERALS, 1977

Mineral	World Rank	% of World Total
Nickel	1	29.9
Zinc	1	19.7
Asbestos	2	26.6
Potash	2	22.7
Uranium	2	19.8
Molybdenum	2	17.4
Elemental sulphur	2	16.7
Gypsum	2	11.0
Titanium	3	17.4
Silver	3	13.0
Platinum group	3	7.3
Gold	3	4.4
Copper	4	9.5
Lead	4	8.9
Aluminum	4	6.8
Iron	5	6.5
Cadmium	6	6.7

Source: Dep. Energy, Mines and Resources, 1980d.

ECONOMIC OUTLOOK

In the decade to 1990, according to a Energy, Mines and Resources Canada forecast (Jeffrey, 1980 and Dep. Energy, Mines and Resources 1979e) the real production of the non-fuel mineral industry will grow at an average annual rate of 2.5 percent, compared to a projected real growth for the Canadian economy of 3.8 percent per annum (Table 25). The forecasted value of production in 1990 is expected to be nearly $32 billion compared to $14 billion in 1980. However, this represents a decline in the share of GNP from 4.8 percent in 1980 to 4.3 percent in 1990. In terms of exports, growth in the non-fuel sector is expected to be 2.8 percent per year in real terms, but this will generally be lower than the projected world demand for minerals. Canadian exports are expected to increase at a 10.4 percent per annum rate, but mineral exports will be slightly less at 9.4 percent implying an overall market decline. Employment is expected to increase at an annual rate of 1.1 percent, but net gains will not reflect the number of new jobs created. This is largely due to the significant number of mine closures that can be expected during the same period. Total capital investment requirements are forecasted at $42 billion in constant 1979 dollars to 1990. Half will be required to develop new mines and smelters (or expansions) and the remainder to repair or replace worn-out equipment. However, inflation rates between five and ten percent per annum are likely to see this figure increase two to three times. When capital expenditure requirements for

MAP 18. REGIONS HAVING SIGNIFICANT NON-DEVELOPED MINERAL AND ENERGY POTENTIAL

METALLIC:

1 Bathurst (Pb, Zn, Cu)
2 Chibougamau (Cu, Au, Ag)
3 Northwest Quebec (Au, Cu, Ag, Zn)
4 Sudbury-Elliot Lake (Ni-Cu, U)
5 Timmins-Porcupine (Au, Ag, Cu-Zn)
6 Northwestern Ontario (Au, Ag, Cu, Zn, Fe)
7 Flin Flon-Thompson (Ni, Cu, Au, Ag, Pb)
8 Baker Lake (U, Au)
9 Athabasca Sandstone (U)
10 Great Slave Lake (Au, Ag, Pb, Zn, Cu)
11 Southern British Columbia (Cu, Mb, Au, Ag)
12 Northern B.C.-Yukon (Pb, Zn, Au, Ag, Cu, Mb)

COAL:

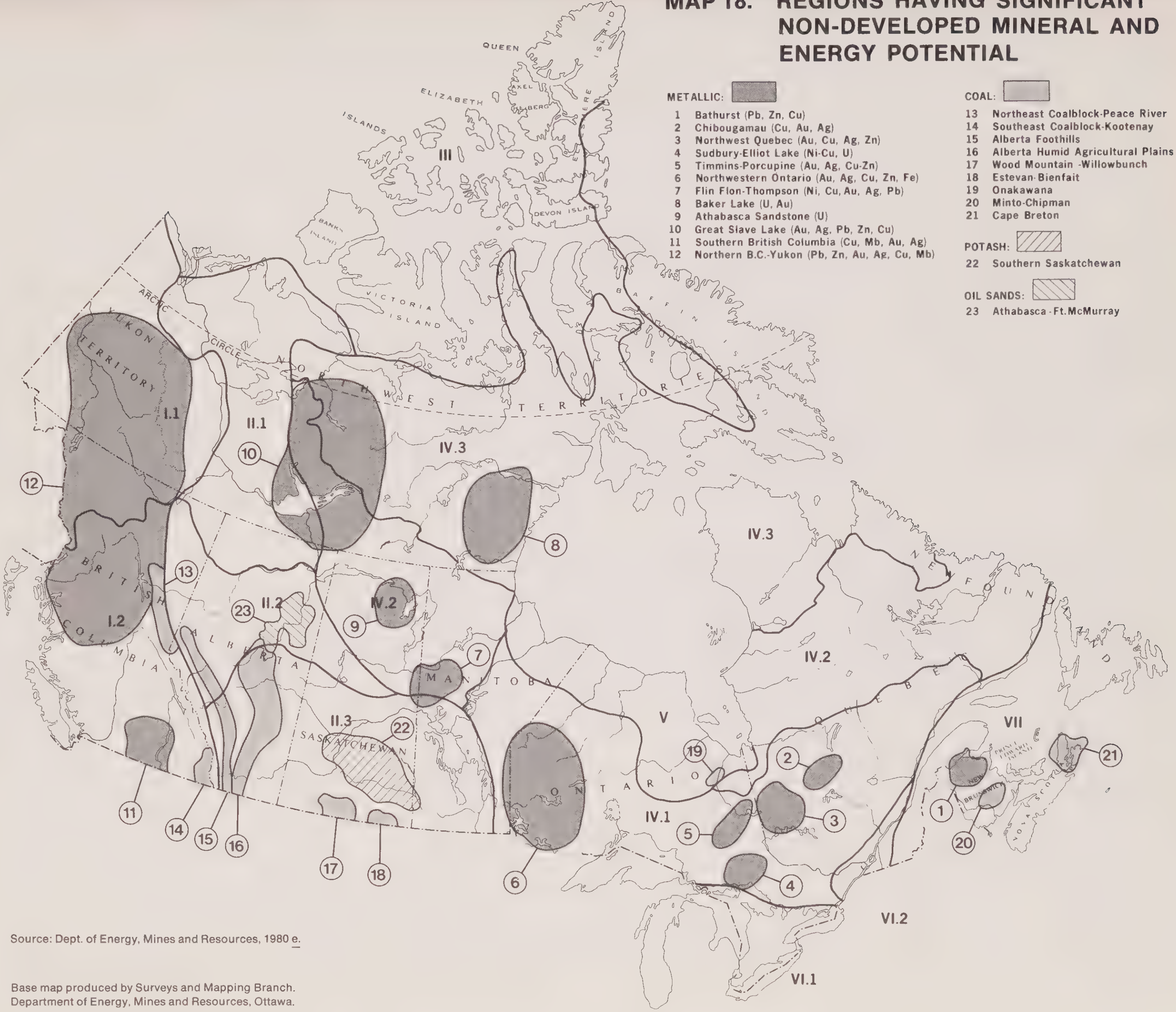
13 Northeast Coalblock-Peace River
14 Southeast Coalblock-Kootenay
15 Alberta Foothills
16 Alberta Humid Agricultural Plains
17 Wood Mountain -Willowbunch
18 Estevan-Bienfait
19 Onakawana
20 Minto-Chipman
21 Cape Breton

POTASH:

22 Southern Saskatchewan

OIL SANDS:

23 Athabasca-Ft.McMurray



Source: Dept. of Energy, Mines and Resources, 1980 e.

Base map produced by Surveys and Mapping Branch.
Department of Energy, Mines and Resources, Ottawa.

oil, gas, coal, and uranium are taken into account, the combined figure in 1979 dollars is likely to be in the $150 billion range. Most new energy projects will continue to become very large with correspondingly large amounts of capital required. In attempting to achieve energy self-sufficiency in Canada, it may create a capital squeeze for the mineral sector. Canada does however, have a large and continuously growing inventory of already-discovered mineral and energy deposits (coal, uranium, oil sands) from which substantial additional new mines and increased production could be developed, provided market conditions are favorable (Map 18). It is unlikely that a resource boom similar to that of the 1950's and 1960's is likely to return (*see* Table 25). However, recent capital spending estimates for new developments reached over $8.6 billion for 1980 indicating that mining is on a cyclical upswing once again (Pabst, 1980; Roberts, 1981). Although some individual mineral and energy products will continue to do well (gold, silver, copper, lead, zinc, cobalt, molybdenum, coal, potash), many will continue to suffer lower rates of growth, and even short-term declines (iron, asbestos, uranium, and, to a lesser degree, nickel).

POTENTIAL CONSTRAINTS

Global Market

It is not surprising that the growth of the mining industry is dependent on exports and international markets. In terms of Canada's overseas markets in 1979, almost 60 percent of all mineral exports go to the United States, 18 percent to the European Economic Community, and just under 10 percent to Japan. These figures indicate that the future health of Canada's mining industry will depend on the ability of the western economies (OECD countries) to recover from the effects of rising energy costs. In general, there will be a declining rate of growth in the consumption of metals in the next five years. In addition to crippling energy costs, world-wide demand for mineral products will be dampened by high unemployment and inflation, slow rates of growth in western countries, the impact of the weak United States economy, and widespread BOP deficits (Chambers, 1980). More important to Canada, is the dominant role that the United States' market plays. The percentage of our mineral exports to the

TABLE 25. GROWTH RATES OF CANADIAN MINERAL PRODUCTION, 1961-1985
(%)

Period	Mining	Primary Metals	Non-Metallic Mineral Products	Mineral Industry
1961-1965	4.7	9.3	11.0	7.1
1961-1970	5.0	6.1	4.3	5.3
1961-1975	3.2	4.5	5.2	4.1
1961-1978	2.4	4.5	5.2	3.7
1961-1985	3.0	4.0	4.4	3.6
1979-1985	2.2	2.6	3.0	2.5

Source: Dep. Energy, Mines and Resources, 1979e.

United States is likely to increase as the United States depletes its own mineral resource base and becomes increasingly vulnerable to offshore disruptions of mineral supplies (Jeffrey, 1980). Of increasing importance are the many internationally traded minerals that can be called "strategic or critical" to western industrial economies due to world political and economic instability. The list will vary from country to country. They generally include cobalt, chromium, vanadium, silver, titanium, platinum, manganese, phosphate rock, diamonds, tin, mercury, and nickel. Canada still remains one of the few countries in the world which is so diversified in its mineral exports that it is capable of adjusting to many potential disruptions. The Canadian Mining Industry, however, cannot stand still if it is to maintain its lead as a world exporter. Its share of the global market can be affected by increased international competitiveness from the rise of new overseas mineral sources. This share may be affected by increased multi-lateral trade agreements between major western consuming nations and new sources in the lesser developed countries. There may be a rise in demand for protected markets for mineral production by lesser developed countries. Associated with this trend is the potential for increased competition from state-owned or controlled producers in the market place. This coincides with a growing trend in all nations towards greater government intervention in the market place, particularly with regard to resource development, and this despite the considerable support for free trade. Of potential long-term concern will be the uncertainty of sea-bed mining due to the lack of a "Law of Sea" settlement. This could have a significant effect on mineral development in Canada due to the high amount of nickel, copper, iron, cobalt, and manganese in the sea-bed nodules. This is unlikely to affect future market structures until the 1990's on both legal and technological grounds.

Energy

Although Canada's diversified energy potential will play an important role in maintaining its percentage of world mineral markets, technological changes will be required. Most mining and processing technologies are energy intensive and becoming more so. Increasingly, energy utilized by mining will come from non-renewable sources — coal, gas, and nuclear-fired generating stations. Thus access to, and availability of, these alternate energy sources will play an important role in the future development of mines, particularly in more northerly settings. Much of this high demand is related to the fact that lower-grade ores generally require more energy for extraction, processing, and refining at a time when energy costs are projected to increase dramatically in the next five years. In the future, the utilization of lower-grade ores will increase. Technological improvements in rock disintegration, concentration, and transport will have to be made if low-grade ores are to be considered as viable reserves.

The drive to conserve energy throughout the world has also had indirect effects on the mining industry. Consumption of certain metals is declining in response to technological changes. For example, the reduction of weight in vehicles through the use of substitutes — plastics, fibreglass, and aluminum — has reduced demand for iron and steel additives. It has also led to a dramatic return to, and demand for, coal throughout the world. In this sector of mining, Canada is likely to see a much higher rate of growth than most other sectors of the industry. However, delays in technological developments related to liquefaction, fluidized bed combustion, and some environmental controls may still limit growth in western Canada.

Exploration

The discovery of new ore bodies is requiring increasingly technical expertise, along with larger sums of money simply to get projects started. Because it is so highly technical, and requires expensive and sensitive equipment often for short-term programs, a large proportion of exploration work is carried out by a variety of consulting and service companies or by local prospectors with a unique knowledge of the area. Major trends in exploration in the next decade are likely to include (Laughlin, 1980):

(i) Increased domination by better-financed companies or consortiums;
(ii) Increased government participation as an initiator or "partner by statute" in exploration;
(iii) More activity by Canadian exploration companies in foreign countries, as well as shifts in activity from one Canadian province to another in response to changing political climates; and
(iv) More emphasis on obtaining basic geological information (drilling and geophysical techniques) particularly about as yet undetected deep ore bodies. Airborne methods will decline in importance except in relatively unexplored remote areas.

These trends are likely to be influenced by internal factors such as technological breakthroughs in exploration equipment that can detect deep ore bodies or improved mining and metallurgical techniques that

allow the exploitation of lower-grade ores. In terms of the structure of the industry, there will be a growing trend towards large, vertically integrated corporations that control the source of their raw materials and the successive steps in extraction and processing (Laughlin, 1980).

Infrastructure

The movement of ores and refined mineral products, often over great distances, is a major element in the economic viability of the mineral industry. Likewise, the existence and low cost of transport between the industrial metropolitan centres and their hinterlands is also essential to other industries in Canada. Co-ordination and planning by both the government and the mineral industries in this regard is a most important factor in the maintenance of healthy mineral industry and Canadian economy. On the one hand the industry does not appear able to afford the high cost of facilities such as roads, railways, and ports that are often essential to the realization of exploitation of a new ore body. On the other hand, the frequency of use required to keep expensive transport facilities in operation and available to other industrial and public uses is a problem common enough in Canada that it often inhibits infrastructure growth. Therefore, any major contribution to the long-term viability of such facilities is of considerable importance.

It is of no small consequence then, that approximately 58 percent of the total rail freight, close to 50 percent of the total freight moved by ship in the St. Lawrence Seaway, and almost 60 percent of the goods loaded in Canadian ports for export are directly attributable to the mineral industry. Mining has been, and continues to be, a major factor in the development of Canada's transportation network.

At the same time, mining developments can be very sensitive to transportation costs. The overriding concern in most potential mineral developments is the effect which transportation costs will have on the marketability of the mineral being sought, particularly with respect to rail transport. Mineral policies usually dictate that the producer bears the transport costs to processing plants or end users (Brown, 1979). Since most minerals are shipped from mines as ore concentrate or equivalent forms, the costs often constitute a significant share of the delivered market value.

Bulk transportation facilities will, therefore, play a vital role in the successful development of the projected new mine ventures outlined earlier in this chapter. The following examples will illustrate just how important a factor transport and related infrastructure requirements will be. Over the past decade, the development of the northeast coal block in British Columbia has been dependant upon securing overseas markets, which in turn depended on the establishment of entirely new and upgraded transportation facilities. The region requires new roads, a rail spurline, and port facilities in addition to the upgrading of existing rail lines to Prince Rupert. Total infrastructure costs are in the neighborhood of $500 million, much of which will be provided by federal and provincial funds.

Coal port, Roberts Bank, British Columbia
NFB — Phototheque — ONF, George Hunter

More important to future Canadian mine development is the cumulative effect that increased production of coal, potash, sulphur and grain in western Canada will have on rail transport. In 1979, all four commodities accounted for 28.1 million tonnes, or 80 percent of the total shipped from the ports of Vancouver and Prince Rupert. By 1985, export shipments are expected to reach 45 million tonnes for the same commodities (Brown, 1981). Capacity limits of the main lines between the Canadian Prairie provinces and the Pacific Coast are already near capacity. Therefore, rail capacity needs to be expanded rapidly in order to handle any significant increase in future mineral development.

The other major areas of concern regarding future infrastructure needs are the Yukon and Northwest territories. Power and transportation will be key elements in any further attempts to expand mining in the north.

Already, considerable federal support has taken place to develop Canada's newest and most northerly mines at Arvik and Nanisivik. Both are dependent on shipping concentrates out in ice-free waters. Should trends in rising costs for energy and construction continue, many important mineral reserves may not be developed. For example, the development of two new base metal deposits in the north are likely to be dependent on Federal support of transport requirements. Road and rail extensions to the lead-, zinc-, and tungsten-rich Selwyn Mountains in the eastern Yukon and the major base metal deposits east of Great Bear Lake in the Northwest Territories. (Brown, 1980). The latter deposits will be extremely difficult to develop due to extreme distance and remoteness from the nearest transportation network. Indeed, the feasibility of shipping ore or concentrates from a northern port facility on the Coronation Gulf is being considered.

Associated with almost any proposal to develop new transport corridors to a mine are environmental concerns. This usually means the influence of the proposed mine development on the land-resource base becomes much more widespread, attracting considerably more attention than would be the case in an established mining region. Under the circumstances, the time required to achieve environmental approval may be considerably longer.

Uranium mine on Lake Athabasca, Saskatchewan
NFB — Phototheque — ONF, George Hunter

The success of many future mine developments may depend solely on the provision of the necessary infrastructure — transport, energy, labour, and community services. If the mining industry cannot self-finance difficult or extensive transport facilities on their own, then governments will be forced to invest on a priority basis. Much of this will depend on whether or not considerable social services will need to be established or sufficient long-term socio-economic benefits will accrue. In terms of northern frontier areas, shortages of skilled labour are likely to add to factors that retard the pace of northern mine development.

Regulatory and Jurisdictional

Many constraints on mining are related to regulatory requirements and the various jurisdictions that administer them. Much of the confusion and delay arises from what appears to be a steady increase in government involvement and/or intervention in the industry, and the ensuing overlap of responsibility between, and within, the various levels of government. Of particular interest to this study is the effect that jurisdiction and regulatory controls have over the allocation and management of land resources.

Much of the controversy or delay over mine development comes from conflicting demands over access to, and the use of, lands with marketable mineral and energy resources. Outstanding native claims and innumerable demands for the protection of lands for special purposes (parks, wildlife reserves, etc.) are putting considerable strain on the existing mechanism for integrated resource management. Demands are increasingly being encountered in the public environmental assessment and review process. In response, the mining industry has become increasingly concerned over the complexity and long delays in obtaining environmental permits to proceed with mine developments. Many of these jurisdictional and regulatory problems associated with the use of land by mining, its impact on the environment, allocation of land resources, and the conflicts between mining and other land uses will be reviewed in more depth in the following chapters.

Open-pit base metal mine, Manitouwadge, Ontario.
NFB — Phototheque — ONF, George Hunter

Chapter Four

LAND UTILIZED AND DISTURBED BY MINING

LAND UTILIZED

The nature and characteristics of the mining industry described previously illustrate the wide range and intensity of land use activities that can take place during the various stages of mining. Millions of hectares may be subject to wide-ranging exploration techniques, but only a fraction is directly affected by the development and production stages. In most cases, the factors determining the area of land affected are (i) the characteristics of the mineral being produced — depth to ore, density and type of mineral; (ii) its ore grade and reserve; (iii) its percentage recovery rate; (iv) the method of mining; and (v) whether or not beneficiation and further processing takes place at the mine site.

The widest geographic distribution of mining activity occurs at the exploration stage. Fluctuations in the supply of, and demand for, mineral products is such that very little activity may occur in a given region or indeed the whole country for extended periods, and then a sudden demand for certain minerals causes a great expansion in exploration. Some of the factors that play an important role in determining the level of exploration activity are illustrated by recent events in Newfoundland and the Northwest Territories.

In Newfoundland between 1977 and 1978, there was a 245-percent increase in claims staked in good standing, and 21 percent increase in the number of companies involved. The reasons given included favourable changes in legislation; strong demand for uranium, gold, chromite, and tungsten; increased areas of crown land opened to claim staking; and the publication of new government survey results (O'Driscoll, 1979).

The effect that the demand for a single commodity can have on exploration, and the discovery of a new potential source is illustrated by the current exploration situation in the Northwest Territories. The discovery of uranium in the Baker Lake region by Urangesellschaft Canada Ltd., led to a dramatic increase in uranium exploration. Over 1,573,308 hectares in permits were issued by October 31, 1978. This is 660,000 hectares more than in the 1968 Coppermine rush (Pagham, 1979). The search for uranium has absorbed more than 75 percent of the exploration expenditures in the Northwest Territories.

The rapid increase in world-wide gold prices in the past two years has had a dramatic effect on the Yukon placer mining industry. From a complete termination of activities in November, 1966, placer-mining claims and leases as of July 31, 1979 totalled 6,559. In the subsequent twelve months there was a further increase to 9,716. Over seventy percent of all the claims and leases occurred in the Dawson region (Dep. Indian and Northern Development, 1979*b* and 1980). Much of the increased activity involves the re-working of older placer tailings.

Depending on the time in history and mineral being sought, many areas have been explored and re-explored on several occasions making it difficult to quantify all aspects of the exploration stage, where they affect the land surface directly — through seismic lines, trenches, adits, or drill sites. For the purposes of this study, the major effort to quantify the effects of mining on land use, particularly land disturbances, will be in the development and production stages.

Once exploration has successfully identified a favourable zone worthy of further assessment, provincial and territorial regulations require the establishment of a legal basis for development, either through claim staking, leases, grants, or licenses. The records of these legal requirements provide a good indication of the level of activity at this stage. As of 1979, the mineral sector held the rights to over 39,200,000 hectares or approximately 4 percent of the total Canadian land mass (Table 26). By comparison a further 66 million hectares of on-shore petroleum leases were held by energy producers. These figures fluctuate significantly from year to year, since in many cases it represents only legal title for relatively short periods of time. The total includes properties in production as well as those being evaluated. The land area actually used and disturbed in the exploration, development, and production stages is much smaller.

An indication of the actual amount of land disturbed in relation to the size of area under license or lease for

Noranda Mines Ltd., Geco mine, Manitouwadge, Ontario
NFB — Phototheque — ONF, Crombie McNeill

TABLE 26. LAND HOLDINGS OF MINERAL AND ENERGY PRODUCERS: 1979

Land Uses	Land Holdings	
	(hectares)	
Mineral Development		
Mineral claims and development leases	12,000,000	
Areal grants	24,000,000	
Non-metallic alienations excluding coal	1,200,000	
Coal leases	2,000,000	
Sub-total		39,200,000
Petroleum Leases		
On-shore only	66,000,000	66,000,000
Transmission and Storage		
Petroleum pipelines (gathering and trunk)	1,000	
Natural-gas transmission pipelines	81,000	
Electrical transmission lines	344,000	
Hydro-electric headpond storage	1,619,000	
Sub-total		2,105,000
Grand total		107,305,000

Source: Hamilton, 1980.

exploration activities is revealed in a study conducted in the Northeast Coal Block of British Columbia (Galbraith, 1978). In 1977, there were 721 licenses covering 179,622 hectares, 212 of which were investigated. Exploration and development activities were conducted on 129, disturbing 409 hectares of the land surface (an average of 3.2 hectares per license). Non-mining related disturbances accounted for a further 100 hectares. If all the coal developments investigated were to proceed to the production stage in the Northeast Coal Block, it is estimated that only two to three percent (approximately 3,600 to 5,400 hectares) of the total licensed area would be physically disturbed (McDonald, 1977).

However, given the extent of both mineral and energy (petroleum) exploration activities it is not surprising that the cumulative effects can be widespread. This is particularly true of seismic lines in regions of active

interest. In Alberta's forest zone alone, land disturbance from exploration activities (dominantly oil and gas) amounted to 234,000 hectares, compared to 255,692 hectares cut by normal timber-harvesting operations from 1966 to 1976 (Environment Council of Alberta, 1979). The main effects of exploration are usually confined to one or more of the following: surface disturbance of vegetation; physical changes to soil; erosion and sedimentation; alteration of stream beds; and the displacement of wildlife or alteration of fish habitats.

In the case of diamond drilling, waste water often has a low pH or contains large amounts of suspended solids, heavy metals, or oil and gas leaked or spilled from the equipment (Arkay, 1975). Regulations in most provinces and territories now require that waste water be contained in settling ponds or pits.

F.F. Slaney and Co. (1971) described coal exploration activities and their effects on the surrounding landscape in Alberta as follows:

"Surface trenching is carried out to expose the seams and learn more about the deposit before proceeding with the more expensive drilling operations. To determine the quality of the coal for various markets, it is usually necessary to excavate a test-pit or trench to obtain large samples from beyond the weathered or oxidized zone. This operation often leaves a substantial cut-and-fill excavation on the hillside. On steep hillsides, some excavation may also be necessary to provide level sites for drilling equipment. Roads are built on a short term basis to allow the cheapest access for exploration equipment. The road is made by running a bulldozer through the vegetation, and the surface is usually the coarse fraction of surface soils. Roadside ditches are seldom dug, and crossings over minor streams are usually fords or crude log culverts. After exploration work has been completed, there remains a network of roads, trenches and drillsites extending for many miles, often over very steep slopes. The disturbance of surface soils and vegetation is often severe and long-lasting. The effects are compounded by the steep gradients over many of these roads.

"In the plains, the horizontal coal seams are generally covered with a mantle of glacial drift and are exposed only where major streams have cut deep channels. Thus exploration is mainly restricted to drilling operations, although test-pits must be excavated to obtain bulk samples. In forest areas these activities will also necessitate the cutting of exploration access trails."

Exploration roads and drill sites, Fording Coal Ltd., Elkford, British Columbia
I.B. Marshall, Environment Canada

The actual figures for land disturbance by exploration roadways in the mountains vary. Those calculated by Warden (1976) are 2.5 hectares per 1.6 kilometres (6 acres/mile) of incline with less than 30° slope and 4.5 hectares per 1.6 kilometres (11 acres/per mile) over slopes exceeding that, while Stanlake *et al.* (1975) gives 4.85 hectares per 1.6 kilometres (12 acres/mile).

Although natural processes usually obliterate all signs of activity within a few years, there are many areas in Canada which are highly sensitive to ecological disturbances, particularly in the high altitudes of the Cordilleran mountains and the permafrost zones, across northern Canada. In permafrost zones the natural recovery process is very slow to erase any damage and often there is no recovery when erosion is severe. Most provinces facing these conditions have imposed reclamation requirements as a condition of exploration permit approval.

LAND DISTURBED

In the past decade, there have been three federal studies quantifying the amount of land affected by mineral production in Canada. In 1971, the National Advisory Committee on Mining and Metallurgical Research estimated that land disturbed by mining accounted for 52,610 hectares (excluding mineral aggregates) or about 0.006 percent of the total land (Rabbitts *et al.*, 1971). This figure has been quoted regularly by both government and industry sources. The study projected that the area disturbed would increase to 59,895 hectares by 1975. (Further details of the study can be found in Appendix VI). In 1972, responses to a questionnaire on metal mining by the Water Pollution Control Directorate, Environment Canada, provided a figure of 18,602 hectares disturbed by mines, but did not include coal, potash, gold, asbestos, gypsum, or mineral aggregates. The third and most detailed inventory was conducted by the Canada Centre for Mining and Energy Technology (CANMET) in 1976 (Murray, 1977*b*). The total area affected by mine wastes and open pits (or strip mines) was 58,325 hectares including 7,200 hectares of naturally revegetated or partially reclaimed land. Appendix VII provides a more-complete description of the results of that study.

The prime objective of all three studies was to estimate the amount of land affected by mine wastes and their potential environmental pollution problems. Appendix VIII provides a more-detailed comparison of the results of all three studies. Several omissions or limitations common to all three studies reveal that even the largest figure of 58,325 hectares (CANMET) for mine wastes is extremely low, and does not reflect the true nature and extent of land used or affected by activities related to mine production. Indeed, a recent estimate by the Mineral Policy Sector of Energy, Mines and Resources, Canada, of land disturbance (including structural materials) was placed at 205,000 hectares (Hamilton, 1980).

The major points of omission to be accounted for in order to provide a more-accurate estimate of the land area affected by mining are summarized as follows:

(i) The number of mines investigated was extremely low and confined to operating mines at the time of the study. The exception was the CANMET study which investigated mine sites active in 1968 and 1974. A large number of abandoned mines were omitted.

(ii) Only lands affected by open pits, strip mines, underground shaft sites, tailings, waste rock, overburden dumps, slag, and settling ponds were included (referred to as "Mine wastes"). Land directly utilized for mill, beneficiation facilities, workshops, offices, storage, maintenance, internal transport, and services were omitted (collectively referred to as "Facilities").

(iii) Most important are those land areas alienated from alternative use due to their proximity to, or encirclement by, the "mine wastes" or "facilities". These lands are effectively taken out of alternative land use until mine production is terminated. They are subject to varying degrees of environmental deterioration due to their proximity to, and frequent involvement in, day-to-day mining operations. Indeed, most "alienated" lands are owned or under the direct jurisdiction of the mine operator.

(iv) In most mining situations, depending on the type of operation and mineral being produced, there are "shadow" effects on surrounding land areas due to dust, runoff, seepage, erosion, siltation, traffic, airborne particles, and noise. Generally, land subject to these environmental impacts has not been included in inventories of disturbed or degraded land surfaces due to difficulties in measuring impacts, cost of monitoring on such a scale, and the question of responsibility for undertaking such a task. The shadow effects will be discussed in some detail in chapter 5.

(v) Finally, the areas affected by the ubiquitous construction materials (sand, gravel, crushed stone, etc.) operations were excluded.

Abandoned uranium tailings at Bicroft mine, Bancroft, Ontario
W.B. Blakeman, Environment Canada

Although there are few accurate sources to quantify these omissions, sufficient information is available to provide a realistic "order-of-magnitude" estimate of the amount of land involved. For the purposes of this study the CANMET data was used as a base and modified with more-accurate or current data. The major sources are listed in Appendix IX. In most cases, estimates of disturbed lands obtained from the various sources did not include future reserve areas, or sites occupied by such auxiliary facilities as roads, power lines, loading facilities, repair shops, maintenance equipment yards, offices, and warehouses.

EXTRACTION AND WASTE DISPOSAL

Metallic, Non-metallic, and Energy-related Minerals

In the CANMET inventory of mine wastes the minimum resolution element of LANDSAT satellite imagery used to measure the area of mine wastes was 10 hectares, therefore, any site less than 10 hectares in size was omitted. In addition, a large number of older mines were partially or completely overgrown by natural vegetation. In some situations it was not possible to distinguish between waste rock and natural bedrock exposures. Under these circumstances only 399 of the 718 sites selected had recorded disturbances in the inventory.[13]

Careful use of aerial photography and field investigations would have revealed disturbances at most sites, but such were far beyond the scope and resources of this report. The extent of mining operations in an historical context and, thus, the impracticality of conducting such a detailed Canada-wide inventory is revealed in the results of a study conducted by Environment Canada (Blakeman, 1978).

In 1976, an inventory of those gold mines in Canada, known to practise mercury amalgamation, was conducted as part of a wider study to document the major known sources of mercury contamination in the Canadian environment. Identified were 513 mines practising mercury amalgamation and a further 134 that used straight cyanidation; for a total of 647 mine sites for the period between 1855 to 1975. Not identified were individual mines or prospects for which federal, provincial, or territorial publications indicated that the total production or sample milled was less than 50 tons. In addition, the total did not include base-metal

[13] The provinces in which the most undetected mines occurred were: Ontario, 93; British Columbia, 92; Quebec, 50; Nova Scotia, 29.

Ridge and furrow pattern of coal strip mining in southern Alberta
I.B. Marshall, Environment Canada

mines producing by-product gold unless there was documented evidence of an amalgamation phase in the mill circuit. The Ontario Division of Mines alone had documented the existence of small sample or production mills at many of the more than 1,000 known gold occurrences in the province which reportedly never attained production status.

This inventory of known gold mines indicates why it would be possible to have considerable discrepancies between the various estimates of mine disturbances. It also shows that potentially there is a considerably larger area affected by mining in the historical context, than is revealed by most of the estimates given for land disturbed by current mining operations. In most cases, however, it would be extremely difficult to find any indication of the smaller abandoned sites that existed prior to World War II.

One attempt to document the nature, extent, and seriousness of the environmental problems resulting from active and abandoned mining operations was conducted in Ontario[14]. Much of the area affected stemmed from the early, and relatively unregulated, mining activities that occurred prior to the establishment of current control programs. Of more than 30,000 abandoned sites, identified after their locations were obtained from mining records dating back over 100 years (Castrilli, 1977), no more than 30 to 50 were considered to be contributing significantly to environmental degradation.

Preliminary figures indicated that over 40,600 hectares were affected by mine tailings and associated surface modifications.[15] This figure appears to be high when compared to previous estimates of mine disturbances in Ontario. Watkin and Winch (1973) calculated that tailings deposits alone in Ontario covered some 12,950 hectares. At the time, there were approximately 140 operations extracting metallic and non-metallic minerals and disposing of approximately 80 million tons of tailings annually. The 1976 CANMET inventory gave a figure of 7,800 hectares of tailings deposits at 82 mine sites. The main distinction between the three estimates is the fact that the CANMET and Watkin figures are confined to tailings wastes alone at primarily operational sites. The Ontario Environment inventory included all aspects of mine disturbances, by the use

[14]This was stage 1 of a three-year project funded by a grant from the Provincial Lottery Corporation to clean-up abandoned mine properties under the direction of the Pollution Control Branch, Ministry of Environment, 1977.

[15] Hawley, *Pers. Commun.* 1977.

of large-scale air photos, field surveys, and sampling. A review of land use programs in Ontario (Ward, 1977) provided a fourth estimate of approximately 26,800 hectares disturbed and over 262,000 hectares under license.

A wide range in estimates exists for lands disturbed by mining in Ontario (excluding mineral aggregates). Taking into account the potential number of mine operations that have been abandoned in the past, current operating mines, and all aspects of mine activities that affect the land surface, a realistic figure falls somewhere between 26,800 and 40,600 hectares. The high figure recorded in the Ontario Environment inventory is the most accurate but it includes many sites that are not of immediate concern, that are often too isolated to raise aesthetic concerns, and yet that may have long-range residual pollution problems.

Differences occurred similarly in comparing data sources from other provinces. In Alberta, the Land Conservation and Reclamation Division inventoried all

TABLE 27. ESTIMATED DISTURBED AND RECLAIMED LAND AREAS FOR OPERATING COAL MINES 1979

Province	Type	No.	Average Annual	
			Rate of Disturbance	Rate of Reclamation
			(To the nearest 5 ha)	
British Columbia	O.P.	3	80	100-120[1]
	U.G.	1	minor	---
Alberta	O.P.	4	40	variable
	U.G.	4	minor	---
	strip	5	105	60-130
Saskatchewan	strip	6	190-220	140-190[2]
New Brunswick	strip	1	120-160	100-160[3]
Nova Scotia	U.G.	5	minor	---
	strip	1	5	2-3
TOTALS			Minimum of 540-610	Minimum of 402-603

* Extraction and waste disposal sites.

1 Most of the land reclaimed by the currently operating companies was disturbed by pre-1978 mining activities in the presently producing area.

2 Includes Cornach Mine of Saskatchewan Power Corp., started operations in 1979.

3 N.B. Coal Ltd. has 3 to 7 production sites.

TABLE 28. LAND AREA DISTURBED BY MINING WASTES*

Province/Territory	Metallic and Non-metallic	Uranium	Asbestos	Potash	Coal	Oil Sands	Construction Materials	TOTAL
				(hectares)				
Newfoundland	3,560		217				2,400	6,177
Prince Edward Island							500	500
Nova Scotia	840				360		3,500	4,700
New Brunswick	1,060				4,450		3,000	8,510
Quebec	18,000		2,573				27,000	47,573
Ontario	40,600	857	126				40,000	81,583
Manitoba	1,450						9,000	10,450
Saskatchewan	300	204		3,000	4,860		11,000	19,364
Alberta					6,040	2,800	9,100	17,940
British Columbia	13,223		N/A		5,150		14,500	32,873
Yukon and Northwest Territories	4,125	N/A	173		N/A		N/A	4,298
TOTAL IN CANADA	83,158	1,061	3,089	3,000	20,860	2,800	120,000	233,968

* Mining Wastes are defined in this study to include all lands affected by open pits, strip mines, underground shaft sites, tailings, waste rock, overburden dumps, slag, and settling ponds.

existing coal mine disturbances at 5,491 hectares, as compared to the CANMET inventory of 1,927 hectares, a difference of 285 percent (Thirgood, 1978).[16] The difference for coal disturbances in Saskatchewan was between 3,427 hectares from CANMET and 4,858 hectares by the Province. (Douglas, 1979). Part of the difference is explained by the date of the inventory, all CANMET data is based on 1975 imagery and subject to limitations described earlier.

[16] Valleau, *Pers. Commun.* 1978.

Table 27 provides an estimate of disturbed and reclaimed land areas for operating coal companies on an annual basis. The minimum average annual rates of disturbance and reclamation are 540 to 610 and 402 to 603 hectares respectively. Historically, the cumulative total land disturbance attributable to all coal mines (extraction sites, overburden, and waste dumps) is in excess of 18,000 hectares (abandoned and currently operating).

Taking into account all sources (*see* Appendix IX) the minimum area occupied by 'mine wastes' (excluding

construction materials) was estimated to be 113,968 hectares for all of Canada (Table 28).

Non-metallic Construction Materials

The amount of land disturbed or otherwise left abandoned by the removal of construction materials in Canada is at least equal to, if not greater than, the amount disturbed by all other forms of mining.[17] Although accurate Canada-wide inventories are not available, the existence of several regional and local inventories allows for the estimation of a minimum figure for construction materials.

An initial attempt to provide an order-of-magnitude inventory of land areas in eastern Canada which are or were utilized and possibly damaged in the production of construction materials was conducted as background data for this report (Environment Canada, 1977). The inventory concentrated on those sites that were located near populated centres (more than 500 inhabitants). Due to their nature, construction materials are produced close to the market, since the ratio of their high volume and weight to value makes low transportation costs a key factor in location. Even this limited approach revealed that some 4,997 sites affected 34,072 hectares of land for an average disturbance of 6.8 hectares (7.3 hectares for sand and gravel; 16.7 hectares for quarries). A summary of the findings according to region and province is provided in Table 29. Over 80 percent of the individual sites were found in Ontario and Quebec, affecting 30,832 hectares (20,916 hectares in Ontario).

More-detailed studies at the county and municipal level conducted by the provinces of Nova Scotia and Ontario suggest that the above figure represents only a portion of the total land area affected. Sand and gravel pits in Colchester County, Nova Scotia were not included in the Environment Canada inventory, yet a provincial inventory (Simmons, 1971) identified 126 pits covering an area of 455 hectares. This represents 26 percent of the total for urban-centred regions selected in the Environment Canada inventory. It would appear that the total for the whole province is higher considering the remaining areas not covered by either study.

The Ontario Mineral Aggregate Working Party (1977) reported that there were only 1,200 licensed pits and quarries in the three southern Ontario regions designated under the Pits and Quarries Control Act of 1971, covering 11,534 hectares for an average disturbance of 9.7 hectares. If all the lands in those three regions were designated under the Act, the number of pits would increase to 2,100 and affect an estimated 20,396 hectares. This report did not provide figures for abandoned or previously unlicensed pits and quarries (pre-1971) and those areas not designated under the Act in northern Ontario.

In 1977, estimates by the Ontario Ministry of Natural Resources indicated that 1,497 pits and quarries were licensed under the Pits and Quarries Act, and a further 2,893 to 2,943 were not licensed under the Mining Act on Crown Lands.[18] If the average disturbance figure for the Environment Canada study (6.8 hectares) is used the overall estimate of the amount of land disturbed by pits and quarries in Ontario is in excess of 39,000 hectares (96,370 acres).

In response to the findings of the Working Party, the Ontario Ministry of Natural Resources commissioned two additional studies to further investigate and quantify the amount of land disturbed and rehabilitated to date over a larger area. This included the counties of Brant and Wellington, and the regional municipalities of Durham, Halton, and Peel. It identified 258 sites, covering an area of 10,294 hectares, but limited its investigation to only licensed pits and quarries (Coates and Scott, 1979).[19] Of this total, 33 percent showed that partial, progressive, or completed rehabilitation had taken place. A further 10.9 percent had begun preliminary rehabilitation earthwork. The figure for the same counties and municipalities in the Environment Canada study was 6,567 hectares for disturbed and partially reclaimed land. The detailed, field-checked Coates study, however, more accurately reflects the true situation within the two counties and three municipalities. But even its figures are potentially low, since it excludes unlicensed abandoned operations and wayside pits.

A second commissioned study, conducted by McLellan *et al.* (1979) in the Regional Municipality of Kitchener-Waterloo, provides the only data base available on the number of abandoned and unlicensed pits and quarries in southern Ontario. Of the 246 pits identified

[17] Construction materials, particularly sand, gravel, and crushed stone are often referred to as mineral aggregates. The term as it is used here also includes cement, lime, limestone, clay, and gypsum.

[18] Based on MNR regional staff reports accounting for approximately 95 percent of all pits and quarries, only two regions were not included; northwestern and Algonquin.

[19] Two types of pits and quarries were omitted:

(a) Derelict and/or abandoned sites prior to the *Pits and Quarries Control Act* (1971), which were never licensed or are not in operation after 1971.

(b) Sites which have been completely rehabilitated; put into a new land use, are no longer controlled by the original permit or quarry operators and no longer licensed, as active producing sites, (Coates and Scott, 1979).

TABLE 29. SUMMARY OF LAND AREA DISTURBED BY PITS AND QUARRIES IN EASTERN CANADA*

AREA	Total Area Disturbed	SAND AND GRAVEL PITS		QUARRIES/OPEN-PIT MINES	
		Disturbed Land Area	Mean Pit Size	Disturbed Land Area	Mean Pit Size
		(Area in Hectares)			
Northern Ontario	2,658	2,561	10.4	97	19.4
Western Ontario	6,610	5,667	6.7	943	24.8
Central Ontario	6,820	5,680	9.1	1,140	18.1
Eastern Ontario/Ottawa Valley	4,836	3,935	4.2	901	10.7
Northwest Quebec	452	446	3.5	6	3
Quebec - St. Lawrence Valley/ Eastern Townships	8,821	7,310	6.6	1,511	17.5
Quebec - Lower St. Lawrence	643	643	3.9	-	-
New Brunswick	729	622	3.0	107	5.9
Nova Scotia	1,768	904	4.3	864	29.8
Prince Edward Island	400	400	3.5	-	-
Newfoundland	335	268	3.1	67	5.1
TOTAL	34,072	28,436	7.3	5,636	16.7

* Primarily construction materials.

Source: Environment Canada, 1977.

in the Regional Municipality, 69 were licensed and 177 unlicensed, accounting for 2,416 hectares and 376 hectares respectively. The average size of an unlicensed site was 2.1 hectares, far less than the 35 hectares found at currently licensed operations. The unlicensed category broke down into 103 abandoned and 74 reclaimed or rehabilitated sites. Thus, in the designated townships under the Act, only 15.5 percent of the total licensed area was affected by the unlicensed, abandoned category. But the multiplicity of sites, widely distributed, gives the impression of a much-larger area being affected. The smaller size of abandoned sites reflects the introduction of the 1971 Pits and Quarries Control Act. Operations under license

became fewer but also larger and longer lasting in designated townships. In addition, the Act allowed municipalities the right to use zoning to restrict 'land use' and hence, limit the number of licensed operations and their location. This was not always the case in those townships that were not designated under the Act, or that were far enough away from centres of population to attract public pressure to restrict their operation or rehabilitate abandoned sites (Ontario Mineral Aggregate Working Party, 1977).

The data indicated that far more land in Ontario has been affected by pit and quarry operations than previously known, particularly the cumulative total that remains from the period prior to the 1971 Act. This situation is more or less true for all the provinces, since Ontario introduced the first act in 1971 to attempt to exclusively control pits and quarries and enforce reclamation. It was not until 1973 that similar legislation was passed in Alberta (Land Surface Conservation and Reclamation Act) and 1977 in Quebec. Indeed, it was the same proliferation and lack of control evident in southern Ontario that led to the special regulations in Quebec (Pits and Quarry Regulations under the Environmental Quality Act).

Comparable information for the western provinces is limited but shows that, between 1945 and 1975, within a 48 kilometre radius of Winnipeg the amount of land disturbed by pit and quarry operations increased from 790 to 2,466 hectares, an average of 56 hectares/year (RPC Ltd., 1975). In Saskatchewan in 1975, there were a total of 815 outstanding permits accounting for 16,387 hectares of crown land. Over 80 percent of the pits were used by the Department of Highways (Poliquin, 1977). The actual amount of land disturbed by sand, gravel, and clay pits was 10,926 hectares (Land Use Policy Committee, 1978). The area disturbed in Alberta was 9,090 hectares in 1977, with an anticipated future increase of 4,545 hectares (Thirgood, 1978).[20]

In the light of that information, together with the annual production figure for structural materials, the per capita consumption (13 tonnes/year), and the distribution of population, an order-of-magnitude estimate of the minimum area disturbed by the production of structural materials in Canada (excluding the territories) is 120,000 hectares.

[20] Valleau, *Pers. Commun.* 1978.

FACILITIES AND ALIENATED LANDS

Metallic, Non-metallic, and Energy-related Minerals

The amount of land affected by the facilities and alienated lands categories was estimated from measurements of air photos, topographic sheets with mine layouts, and data available in a number of published studies (Thirgood and Gilmore, 1971; United Kingdom, 1972; Abbott, 1975; Murray, 1977*b*).

The Commission on Mining and the Environment (United Kingdom, 1972) estimated the amount and type of land disturbances that could be expected at three different hypothetical mines (Table 30). The amount of land devoted to 'facilities' varied from 6 to 45 percent, and 'alienated lands' between 7 and 22 percent. The total area within the boundary of the mining site was two to three times the size of the area used for dumping mine wastes. Most of the variation is explained by the difference in ore reserves, ore grade, method of working, percentage recovery rate, and the ratio of waste rock to ore. In a comparison of similar data for operating mine sites in Canada, despite the differences in the type of mineral mined and size of operation, the amount of land affected by fixed 'facilities' remained relatively constant, ranging between 5 to 7.5 percent (Table 31). The land directly alienated varied between 14 to 45 percent. The high alienated land figure for the three asbestos mines reflects the cumulative impact of their close proximity to each other, and as such, would not be a normal occurrence for most mining situations. For the second iron mine listed in the table (number three), the larger than average volume of ore extracted to date, (263 million tonnes of a projected 305 million tonnes) has required several waste-rock dumps thus increasing the amount of land alienated (Abbott, 1975). By comparison the pre-mining estimate for the maximum amount of land to be utilized for mine waste and facilities at the Highland Valley Copper mine in British Columbia was 1,484 hectares, 6.5 percent being devoted to facilities (Thirgood and Gilmore, 1971). The projected figure for the new Afton Mine in British Columbia was 5 percent of 417 hectares (Anderson and Robertson, 1977).

From these examples, the figure of seven percent of the area occupied by mine wastes was taken as being representative of the amount of land occupied by facilities at most mine sites. Similarly, a figure of 30 percent was adopted for the amount of land alienated by the above two groups of mining activities. Using these figures, alienated lands and those occupied by facilities at mine sites account for a further 32,334 hec-

TABLE 30. LAND DISTURBANCE AND USE AT THREE HYPOTHETICAL MINE SITES

Type of Mine	Mine Wastes	Facilities	Alienated Lands	Total area within mine-site boundary
	Waste Rock, Ponds, Tailings, Open-Pit, Overburden Storage	Plant, Mill, Workshops, offices, reservoir etc.		
		(hectares)		
1. Open-Pit Copper Mine 4 million tonnes/year 60 million tonnes reserves	315	20-40	30-70	300-800
2. Open-Pit Lead Zinc Mine 666,000 tonnes/year 10 million tonnes reserves	56	6-15	4-8	100-160
3. Underground Copper Mine 650,000 tonnes/year 13 million tonnes reserves	33	8-15	5	60-160

Source: United Kingdom, 1972.

tares. Coupled with the earlier estimate of 113,968 hectares for mine wastes, the combined total is 146,302 hectares. Table 32 provides a more-detailed breakdown by province and mine type.

Omitted from this estimate are those smelter and refinery operations that occupy land in industrial sites within urban centres, but it is estimated that at least 5,000 hectares are utilized for these operations (Hamilton, 1980). Added to this is the 2,670 hectares site of the new Steel Co. of Canada Ltd. plant at Nanticoke on the north shore of Lake Erie. The excessively large size was designed to provide a buffer zone to meet public demands for an aesthetic and visually unobtrusive site. However, the large buffer zone resulted in an even greater amount of agricultural land being converted to a non-active mineral land use.

In terms of impact, the areas affected by mine wastes have the greatest degree of physical and chemical alteration. The land utilized for the various support and operational facilities will have fewer problems due to chemical alteration, but will require considerable work to clean-up the physical alteration to the land surface. Alienated lands are generally affected by compaction from vehicles, air- and water-borne particles, and localized spills of liquid or solid compounds (oil, grease, chemicals, etc.) normally used in mining operations. The major focus in terms of reclamation (time, costs, and research) will be on the mine wastes.

Non-metallic Construction Materials

In the mining of construction materials, the amount of land alienated is much smaller. No attempt has been made to determine the area required for facilities since most are located adjacent to or in the bottom of the pit

or quarry. Alienated lands are usually limited to the reserve area not yet extracted, protective berms or noise barriers, access roads, and storage. A minimum figure used to estimate the alienated portion of the construction materials sites is 15 percent, thus adding an additional 18,025 hectares for a total of 138,025 hectares. Generally, the amount of land area affected reflects the provincial production figures (*see* Table 32). Ontario is the largest producer of aggregate (34 percent), followed by Quebec (19 percent), British Columbia (13 percent), and Alberta (6.5 percent).

The estimate of 138,025 hectares is extremely conservative due to the omission of accurate nation-wide data on abandoned pits and quarries, and wayside pits used for highway construction. A more-realistic figure would be at least 25 percent greater. This higher figure, however, is tempered by a combination of remoteness, limited environmental hazards, and natural revegetation sufficient enough to blend in aesthetically with the surrounding landscape.

FUTURE LAND REQUIREMENTS

Major trends in the development and supply of mineral and energy resources (discussed in Chapter 3) are already beginning to have a significant effect on the future nature and extent of mining in Canada. The rapid demand for alternative sources of energy has led to an accelerated expansion of coal, uranium, and oil sands developments. In almost all cases, surface mining is being proposed. Equally important has been the volatility of demand for gold and silver, and other strategically important minerals. This is particularly sig-

TABLE 31. LAND DISTURBANCE AND USE AT OPERATING MINE SITES IN CANADA

Type of Mine	Mine Wastes	Facilities	Alienated Lands	Total Area Within Mine Site Boundary
	Waste Rock, Slurry Ponds, Tailings, Open Pit, Overburden Storage	Plant, Mill, Workshops, Offices, Reservoir, etc.		
		(hectares)		
1. Open-Pit Copper-Silver Mine, British Columbia	1,018	75	205	1,298
2. Open-Pit Iron Mine, Labrador/Newfoundland	553	54	185	792
3. Open-Pit Iron Mine, Quebec	607	30	245	882
4. Open-Pit Iron Mine, Quebec	289	35	40	364
5. Asbestos Mines three adjoining open-pit mines; combined area, Quebec	1,060	54	480	1,594

Sources: Abbott, 1975; Murray, 1977b.


Bethlehem
Lornex

Growth of open-pit mining operations from 1971 to 1975, Bethlehem Copper Corporation and Lornex Mining Corporation Ltd., Highland Valley, British Columbia. *Original photos supplied by the Surveys and Mapping Branch, Department Energy, Mines and Resources. A24113-113 and A2417-237*

TABLE 32. LAND AREA DISTURBED, UTILIZED AND ALIENATED BY MINING*

Province/Territory	Metallic and Non-metallic*	Uranium	Asbestos	Potash	Coal	Oil Sands	Construction Materials	TOTAL
				(hectares)				
Newfoundland	4,880		297				2,750	7,927
Prince Edward Island							575	575
Nova Scotia	1,150				495		4,025	5,670
New Brunswick	1,450				6,100		3,450	11,000
Quebec	21,885		3,525				31,050	56,460
Ontario	48,420	1,174	173				46,000	95,767
Manitoba	1,986						10,350	12,336
Saskatchewan	411	279		4,110	6,660		12,650	24,110
Alberta					8,280	4,850	10,500	23,630
British Columbia	18,115		N/A		6,175		16,675	40,965
Yukon and Northwest Territories	5,650	N/A	237		N/A		N/A	5,887
TOTAL	103,947	1,453	4,232	4,110	27,710	4,850	138,025	284,327

* Includes land area disturbed by mine wastes and facilities and those land areas alienated from alternate use due to their proximity to, or encirclement by, mine wastes or fixed facilities.

nificant for many formerly marginal mines which, while originally closed down due to low prices, are now viable again. This has extended the life of existing mines, re-opened formerly unprofitable ones, and, now that the price per g/kg (oz/lb) is high enough to make their ore grades and reserves profitable, has led to the rapid development of several new mines. The generally favourable climate for mine development (over the long run) and the importance of mining to Canada's economy will ensure an increase in the amount of land required for mining purposes.

METALLIC AND NON-METALLIC MINERALS

Land Requirements

Scott and Bragg (1975*a*) have indicated that the disturbed area attributable to all mining activities was growing at the rate of 3,600 hectares per year, with coal, iron ore, and non-ferrous metals contributing more or less equally. Some indication of the rate of growth at existing open-pit metal operations is

TABLE 33. ESTIMATED LAND AREA UTILIZED FOR CANADIAN SAND, GRAVEL, AND CRUSHED STONE PRODUCTION COMPARED WITH ANNUAL PRODUCTION 1980-2000

Year	Production (a) (b)		Land Utilized (c)	
	Sand & Gravel	Crushed Stone	Sand & Gravel	Crushed Stone
	(Millions Tonnes)		(Hectares)	
1980	327	103	6616	1250
1985	375	124	7588	1505
1990	430	145	8700	1760
2000	568	198	11493	2407

(a) Canadian Mining Journal, 1981.

(b) 1985, 1990, 2000 production forecast based on annual growth rate forecasts of 2.8 percent for sand and gravel and 3.2 percent for crushed stone by U.S. Bureau of Mines (1976).

(c) Conversion factors of 30 acres (12.1 ha)/million tonnes for stone and 50 acres (20.2 ha)/million tonnes of sand and gravel extracted (Barney, 1980).

Sources: United States Bureau of Mines, 1976; Barney, 1980; Canadian Mining Journal, 1981.

indicated by data available on iron-ore mines in Quebec, where in 1974, open pits, waste-rock dumps, and tailings affected 3,027 hectares of land. The projected annual rate for similar disturbance is 302 hectares until 1994, for a total of 9,065 hectares since the start of mining (Abbott, 1975).

A general indication of the rate at which the land requirements for metallic and non-metallic mining operations may increase in the near future can be inferred from the information on future mine developments in the previous chapter. At least 13 new mines per year would be required by the year 2000, just to keep up Canada's current share of the world markets.

The figures on land disturbed by mine wastes discussed earlier (*see* Table 3), represent approximately 50 to 70 percent of the actual surface area disturbed at a mine site (excludes the areas referred to earlier as facilities and alienated lands). Therefore, using the forecast requirement of at least 13 new mines a year and taking 148 hectares as being representative of the average disturbance over the life of a mine, the minimum annual land requirements for extraction and waste dumps at metallic mine sites would be approximately 1,924 hectares.

A more-realistic order-of-magnitude figure that includes the requirements for facilities and alienated lands would increase this total to at least 3,000 hectares per year. This figure would not account for major expansions at existing mines and reopening of older mines, nor would it provide for on-going pollution control, clean-up, and reclamation during the life of a mine.

Projected to the year 2000, the cumulative increase in land disturbed would be approximately 60,000 hec-

tares for metallic and non-metallic mines (excluding construction materials). These figures do not include the potential areas that may be alienated or adversely affected by effluents or particulate matter beyond the mine site, (i.e. the shadow effect).

There are no accurate Canadian figures on rates of annual disturbance for the construction materials sector or demand projections for future demand. However the direct effects of mining mineral aggregates (sand, gravel, and crushed stone) tends to be roughly proportional to the quantity of material extracted (Paone *et al.*, 1974). In the absence of measured Canadian data, rough estimates can be made by applying a conversion factor to estimates of future production. Canada's methods of extraction and site conditions are very similar to the United States, whose figures on the ratio of aggregate produced to land utilized can therefore be used for comparitive purposes to estimate the amount of land required for future production. Estimated annual land requirements for sand and gravel operations (Table 33) will increase in the period 1980 to 2000 from 6,616 to 11,493 hectares per year. During the same period, crushed-stone requirements will increase from 1,250 to 2,407 hectares per year.

TABLE 34. ESTIMATED AREA OF LAND DISTURBANCES RECLAIMED: 1980*

Province/Territory	Metallic	Coal	Uranium	Oil Sands	TOTAL
			(Area in hectares)		
Newfoundland	25	-	-	-	25
New Brunswick	20	1,780	-	-	1,800
Nova Scotia	N/A	125	-	-	125
Quebec	400	-	-	-	400
Ontario	3,385	-	160	-	3,545
Manitoba	25	-	-	-	25
Saskatchewan	5	1,012	1	-	1,018
Alberta	-	2,650	-	775	3,425
British Columbia	1,595	1,750	-	-	3,345
Yukon and Northwest Territories	25	-	-	-	25
TOTAL (CANADA)	5,480	7,317	161	775	13,733

* Totals do not include construction material sites (sand, gravel, rock quarries) or exploration disturbances. Data based on sources in Appendix IX.

Over a twenty-year period (1980 to 2000) approximately 36,168 hectares of land will be required to meet a forecasted demand of 2.98 billion tonnes of crushed stone. Figures for sand and gravel are 179,063 hectares for 8.85 billion tonnes extracted.

Reclamation Progress

The Canadian metallic mining industry has a relatively long history in the field of reclamation dating back to before World War II. However, much of the attention was focused on the use of revegetation techniques borrowed from agriculture and forest sciences. The main objectives were to reduce erosion, to control contaminated surface runoff, to reduce slope failures, and to improve the general aesthetics and redevelopment of the immediate mine area. Early work at INCO in Sudbury and Hollinger in Timmins was directed at reducing dust from the area of tailings (Weston, 1973; Bell, 1975; Winterhalder, 1978).

Prior to the introduction of reclamation requirements in legislation of the early 1970's, the report of the National Advisory Committee on Mining and Metallurgical Research (Rabbitts *et al.*, 1971) indicated that only 637 hectares of mine tailings and waste dumps had been reclaimed at metallic mines (*see* Appendix VI). They estimated that this figure would increase to 2,246 hectares by 1975 under the impetus of new legislation and research activities. However by the end of the 1970's, progress in reducing the backlog of mine disturbances has been slow. A review of reclamation activities across Canada (conducted as part of this study but to be published separately) indicates that the amount of reclaimed mining wastes in the metallic sector of the industry is approximately 5,480 hectares (Table 34).

There are many reasons for the relatively slow progress to date, some of which are listed below:

(i) Actively enforced legislation has only been a product of the 1970's, and only to varying degrees of success in the different provinces.

(ii) Responsibility for abandoned mine sites is still a difficult legal problem in some provinces and indeed, in many cases will ultimately depend on the degree of importance attached to the need for clean-up by the respective provinces.

(iii) Metallic mines operate for extended periods of time (usually between 15 to 20 years) before closing down. Uncertainties during the initial stages and unexpected changes make reclamation planning impossible on active pits, waste dumps or tailings areas. Frequently pits and waste dumps have to be extended due to increased amounts of waste (lower grade ores) or unexpected new ore reserves. In many cases the clean-up and reclamation of land must wait until a waste rock dump or tailings pond is no longer operational, or until the mine finally closes down due to depletion of reserves. Adverse market conditions may further delay clean-up through a series of temporary closures.

As long as mine tailings, waste dumps and extraction sites are still operational very little actual progress is feasible beyond the research area test plot scale.

(iv) The very high percentage of metallic sulphide ore mines reduces significantly the potential amount of disturbed land that can be successfully reclaimed at this time. Although there have been isolated examples of successful reclamation, the low pH's and toxic heavy metal content of pyrite and pyrrhotite sulphide ores has prevented long term solutions even with massive doses of lime or limestone on an annual basis. Revegetated sites continue to require high fertilizer amendments, few can be left untended for any length of time.

(v) Even more serious problems are associated with uranium mine wastes which release radioactive elements into the environment particularly through water bodies. Problems related to uranium wastes are still largely unsolved despite almost a decade of research in the reclamation area (Atkin *et al.*, 1977; Schmidt and Moffett, 1979).

Under the circumstances, it is not likely that the backlog of land disturbed by metallic and non-metallic mines (excluding construction materials) will be reduced at any significantly increased pace in the near future.

The number of companies now involved in reclamation research has grown dramatically in the 1970's. In 1979, in excess of 60 mining companies were involved in reclamation at approximately 130 mine sites. This includes all the currently operating coal companies. Many companies have several mine sites, and research, centred at one or two of the sites, is designed to apply to other sites as well. For example, five currently operating companies operate in excess of 40 different mine sites. In addition, some large companies with their own environmental and reclamation research staffs are now conducting (or advising) recla-

Hydroseeding in progress at INCO site, Sudbury, Ontario.
I.B. Marshall, Environment Canada

Reclaimed tailings pond for wildlife use at INCO mine site, Sudbury, Ontario
I.B. Marshall, Environment Canada

mation work for other smaller, less-experienced operators on contract. In many cases, mining companies have been involved in co-operative research with government agencies or universities at one time or another, or have provided access to, and assistance with, field trials on their mining properties. More and more mining companies are obtaining the services of specialized environmental and engineering consulting companies to design and implement reclamation and long-term land use planning programs.

Much of the research up to the early 1970's emphasized the establishment of vegetation (particularly the use of agronomic species), the development of species that could adapt to the adverse conditions, and the influence of waste characteristics and size variables in plant survival and growth. The early emphasis on this 'hit and miss' agronomic approach has been replaced by an approach that utilizes adaptive native species which can be used for initial stabilization. Further emphasis, particularly with new mines, is being placed on pre-planning environmental protection factors, including the design and placement of overburden and mine wastes and long-term reclamation programs that meet specific land use objectives. Generally this approach is more effective and reduces the total clean-up costs.

In metallic mining (and some non-metallic), there are many cases, particularly with uranium and sulphide ores, where reclamation is not feasible and other solutions are required. Around the waste storage sites with no prospect of alternate post-mining land use buffer zones may be necessary. Future decisions on the use of land may have to take this into consideration before allocating land to certain mining activities or until newer technology allows solutions. If certain mine wastes cannot be reclaimed then concepts of post-mining use — especially sequential or multiple use — will have to be abandoned and those of highest or best use, based on socio-economic cost-benefit analysis, may have to play an even more important role than they do at present.

Although very little information is available Canada-wide to assess the scope of future construction materials operations, there is some indication that progress in reclaiming abandoned pits and quarries is being made. The main incentive has been legislation, potential profit, and pressure from the public and local municipalities. Most of the progress is being made by the large, currently operating companies (Coates and Scott, 1979; Yundt, 1977). In some provinces, programs have been initiated to clean-up the backlog of disturbed sites, with public funds (Alberta, Saskatchewan, and Ontario). In most cases, the reclaimed sites have been located within the boundary of expanded urban centres, and usually the prospect of a significant profit to be gained from improved land values has been a prime motivator. Most sites have been successfully reclaimed and developed into landfill sites, playgrounds, parks, golf courses, campgrounds, gardens, and industrial and residential sites.

A recent study identified 82 pits and quarries within the Metropolitan Toronto Region (Yundt and Augastis, 1979), 67 of which had been rehabilitated. Of those rehabilitated, 34 percent are now used for recreational, 27 percent for residential, and 13 percent for educational purposes. Two of the sites were incorporated in the Metropolitan Zoo. There have been few cases of reclaiming lands back into agricultural production.

Positive benefits have been gained by many municipalities in that the isolated pockets of abandoned undeveloped extraction sites have provided opportunities to develop areas much needed for public use which were neglected in the initial thrust of urban development. Even so, it is unlikely that the huge backlog of abandoned sites (especially wayside pits) in Ontario and Quebec will ever be entirely reclaimed. In the future, the potential profit motive and/or municipal (township or county) planning requirements coupled with enforced legislation requiring reclamation to a designated land use will be the major focus in reducing the cumulative total of lands affected by construction materials operations.

Currently operating mines will ultimately have to clean up existing operations to varying degrees according to provincial requirements and the degree of enforcement. In many provinces, reclamation programs are now put on a priority basis related to the degree of hazard involved and the availability of funds (Marshall, in preparation).

ENERGY-RELATED MINERALS

Coal

Land Requirements

With an estimated three-fold increase in surface-mined coal over the next twenty years in Canada, future mining activities will have significant effect on land requirements. Based on projected forecasts (*see* Chapter 3), the rates have been estimated at which lands will be

TABLE 35. ESTIMATE OF DISTURBED AND RECLAIMED LAND AREAS ASSOCIATED WITH NEW OR EXPANDEDSURFACE COAL MINES: 1980-2000

Province	No. of New/ Expanded Mines	Anticipated Annual Production	Type	Estimated Annual Area Disturbed	Estimated Annual Area Reclaimed	Comments
		(tonnes)		(hectares)	(hectares)	
British Columbia	1	10,700,000	O.P.	65	35	Hat Creek - 1,050-ha pit to be partially backfilled or allowed to flood at end of 35 years. Overall disturbance for Phase I will be 2,250 ha. Waste dumps to be reclaimed.
Alberta	5	20,000,000	Strip	335	255 - 420	Includes three new mines (Genessee, Sheerness, Paintearth) and the expansion of two current operations (Highvale, Vesta). Unexpanded existing mines will disturb approximately 55 ha annually until closure. Thus the provincial strip-mine total will be in the range of 590 ha/yr.
Saskatchewan	1	1,680,000	Strip	90 - 110	60 - 120	The five existing mines will disturb 100 - 110 ha and reclaim 100 - 120 ha annually, thus the total disturbance will be in the range of 190 - 270 ha/yr.
Ontario	1	2,000,000	Strip	170	150 - 190	Potential development of low-grade Onakawana Lignite.
New Brunswick	1	600,000	Strip	120 - 160	100 - 160	Expansion of N.B. Coal Ltd., production from 0.3 to 0.6 million tonnes/yr.
Nova Scotia	1	70,000	Strip	20 - 25	15 - 30	Potential development of three sites over 20 years by Novaco.
TOTALS		35,050,000		800 - 865	615 - 955	

Source: Blakeman, 1980.

disturbed and reclaimed, during the period from 1980 to 2000 and are presented in Table 35. Again, areas include only those lands disturbed or reclaimed as a consequence of the extraction processes, rather than those committed to ancillary functions (facilities, alienated lands, or reserves).

From these estimates it can be seen that the annual land disturbance from new, or expanded, surface coal-mining operations in Canada can be expected to average in the range of 800 to 865 hectares (*see* Table 35). Over a twenty-year period this would amount to 16,000 to 17,300 hectares. The most-significant increases in land requirements will come from operations in Alberta, Saskatchewan, and New Brunswick. The disturbance rate in Alberta and Saskatchewan combined contributes to more than half of the total, and will probably be in the order of 400 to 500 hectares per year. The lands affected in these two provinces can be expected to consist of either cropland, grazing lands, or forests. The Hat Creek, British Columbia and Onakawana, Ontario coal mine and thermal power-station projects are still in an on-again/off-again status due to potential environmental damage from the high sulphur content of the coal and/or unique geographic location of the proposed sites.

A much-larger Alberta forecast projects a maximum development of up to 143 million tons per year (including gasification and petrochemical complexes) or 68,798 hectares disturbed over a 30-year period between 1975 and 2004 (Hermans and Goettel, 1980). This projected forecast would result in approximately 2,293 hectares per year being disturbed. However, it seems unlikely that such a dramatic increase in the domestic market will be realized.

The proposed new and expanded mines can be expected to increase the total amount of land that could be disturbed by coal mines to between 1,075 and 1,150 hectares annually at least until the mid-to-late 1980's. This figure does not include an estimate of the amount of land that will be required for projected new coal mines in the Sukunka and Quintette areas of the Northeast Coal Block, and a smaller coal basin east of Prince George in British Columbia. If all operations in the area were to proceed, anticipated annual disturbances would increase by approximately 50 to 75 hectares.

Reclamation Progress

Progress in reducing the amount of land disturbed by coal operations in Canada is largely a reflection of more-stringent legislation passed in British Columbia (1968), and Alberta (1973) requiring reclamation and more-recent measures in Saskatchewan, New Brunswick, and Nova Scotia that promotes reclamation through the use of new legislation policies and environmental impact assessment requirements. At this time, all currently operating coal mines are actively involved in reclamation work. In view of existing rehabilitation requirements in most of the producing provinces, it can reasonably be assumed that concurrent reclamation will be practised at essentially all of the currently operating, new, or expanded mines (open-pit or strip), and that the disturbed lands will be rehabilitated to conditions acceptable to the respective provincial governments. Indeed, from existing company plans it is expected that annual reclamation rates at new and expanded mines could range from 615 to 955 hectares (*see* Table 35) and from 235 to 320 hectares for existing mines (*see* Table 27). The variation in reclamation rates can be due to:

(i) Differences in operating conditions at individual mines which can dictate that in some years the land disturbance rate will exceed the reclamation rate whereas in subsequent years the reverse could be true; and
(ii) Conditions written into the provincial mining leases granted to the operators which can require them to rehabilitate lands within their lease areas which had been disturbed by mining operations conducted prior to the late 1960's.

In spite of reclamation programs which have been carried out by the industry in conjunction with surface mining operations in recent years, extensive areas of derelict land remain at abandoned mine sites in all of the producing provinces. Up to 1979, the backlog of land disturbance (extractive sites and waste dumps only) is estimated at approximately 18,825 hectares, of which approximately 30 per cent has been reclaimed to date. This does not include those areas affected by permanent facilities or alienated from alternate use, which would increase the area affected to some 25,790 hectares. Much of the unreclaimed land can be categorized as orphan lands or those which were disturbed prior to regulatory requirements for reclamation. Within the major strip-mining provinces of Alberta, Saskatchewan, and New Brunswick, the figure falling into this category is as high as 10,000 hectares.

The eventual rehabilitation of this land would have to be undertaken by provincial agencies either alone or in concert with the mining companies. Both Alberta and British Columbia have initiated long-term rehabilitation programs directed towards the final clean-up of all abandoned coal mining areas not the responsibility of

Overburden spoil piles at a coal strip mine being levelled for revegetation in southern Alberta
I.B. Marshall, Environment Canada

Crop production on reclaimed coal strip mine in southern Alberta
I.B. Marshall, Environment Canada

currently operating mines. Because the current or future cost of reclamation may far outweigh the benefits to be derived from long-abandoned lands, significant proportions of this derelict land in Saskatchewan and New Brunswick may never be reclaimed. Indeed, it seems likely that much of the 6,500 hectares of abandoned coal-mined land in these two provinces may fall into this category. These provinces are concentrating on the concurrent reclamation by operating companies. It is unlikely, however, that the previously estimated figure of 25,792 hectares disturbed and alienated by all existing and abandoned coal mines will ever be achieved again. The total should decrease with time as existing and proposed reclamation plans become fully operational, provided that they are implemented.

Oil Sands

The maximum potential area that could be affected by surface extraction of oil sands is approximately 230,000 hectares. The proposed new Alsands plant in the Fort McMurray region is expected to be about the same size as the existing Syncrude plant (159,000 m^3/day of synthetic crude oil) which would be expected to directly disturb at least another 8,900 hectares of land. However, as described in Chapter 2, problems with the physical nature of the tailings have delayed attempts to find a method of reclaiming them. The high water content of sludges requires storage behind dykes with little possibility of revegetating the surface at this time. In addition there is concern that the initial tailings ponds in the various proposed projects may result in the permanent loss of oil resources locked up in the underlying oil sands. To date, reclamation has been confined to the dykes and other non-extraction or tailing areas, resulting in the establishment of a vegetative cover on some 775 hectares of land by 1979.

SYNOPSIS

The amount of land affected by the mining industry is considerably more than previous studies have indicated on a nation-wide basis. The fullest dimension of mining is reflected in the exploration phase of mining which is subject to significant fluctuations from year to year, and often represents only very short-term influences on land use. Accurate data to define and characterize the true extent of exploration disturbances in the mining industry is still lacking.

The total land area disturbed, utilized and alienated by mining activities is estimated at 284,327 hectares, and is equivalent to approximately half the size of Prince Edward Island. A third of the disturbance occurred in Ontario, one-fifth in Quebec, and fifteen percent in British Columbia. In terms of impact, the areas affected by 'mine wastes' (233,968 hectares) have the greatest degree of physical and chemical alteration. The land utilized for various support and operational 'facilities' will have fewer problems of chemical alteration but will require considerable work to clean-up the physical alteration to the land surface.

The estimated land area disturbed, utilized, and alienated by the metallic and non-metallic mineral sectors (excluding construction materials) is 112,289 hectares. Smelter and refinery operations located in industrial sites within urban centres utilized an additional 7,670 hectares. At the forecast rate of mine development, minimum estimates indicate an increase in land requirements for the same metallic and non-metallic sector would increase by approximately 60,000 hectares, over a twenty-year period ending in 2000 AD.

The minimum area disturbed and alienated from use by the extraction of non-metallic construction materials is estimated at 138,025 hectares. The uniqueness of this figure is that it represents thousands of individual pits and quarries, the majority of which can be found within an eight-kilometre radius of most populated centres. Over the next twenty-year period (1980 to 2000) an estimated 215,231 hectares of land will be required to meet forecasted demands for construction aggregates (sand, gravel, and crushed stone).

The energy-related sector of mining affected a further 34,013 hectares of land. The projected three-fold increase in surface-mined coal over the next twenty years in Canada will result in an additional land disturbance of between 18,000 to 20,000 hectares. The expansion of oil sands operations in the immediate future (pre-1990) is confined to a single new plant that will disturb at least an additional 8,900 hectares. The maximum potential area affected by all existing and proposed oil sands sites is estimated at approximately 30,000 hectares, including facilities, wastes, and alienated lands.

All aspects of mining in the next twenty years are together likely to utilize or disturb in excess of 300,000 hectares.

The amount of land reclaimed to date (1980) in the metallic and non-metallic sectors is 5,480 hectares, which represents slightly less than five percent of the total area affected by mine wastes at metallic and non-metallic mine sites. It is not likely that the backlog of land disturbed by metallic and non-metallic mines will be reduced at any significantly increased pace in the near future. Concurrent reclamation will be practised at

essentially all currently operating and new or expanded coal mines. Annual reclamation rates at new and expanded mines will range from 615 to 955 hectares and from 235 to 320 hectares for existing mine sites. Already, approximately 35 percent of the backlog of land disturbance at coal mines (approximately 20,860 hectares) has been reclaimed or is in various stages of reclamation.

Much of the unreclaimed land can be classified as orphan lands or those which were disturbed prior to regulatory requirements for reclamation. Because current and future costs of reclamation may far outweigh the benefits to be derived from long-abandoned lands, significant proportions of this derelict land in Saskatchewan and New Brunswick may never be reclaimed. Approximately 6,000 hectares may fall into this category. In Alberta, the backlog of orphan lands is being reclaimed by the provincial government.

A successful reclamation technique for tailings at oil sands plants has yet to be found. However, a concentrated research program is continuing to pursue a solution. Reclamation activities to date have been confined to revegetating the dykes.

There is insufficient data available to provide any estimate of the amount of reclamation conducted at construction material sites across Canada. There are, however, few physical and chemical factors limiting reclamation at these sites (with the exception of quarries), and indeed, there are a large number of rehabilitated sites across Canada, where sufficient economic incentive has prevailed. The large backlog of unreclaimed pits and quarries is generally attributable to lack of reclamation requirements or the failure to enforce regulations in the past.

The emphasis in this chapter has been on the land actually disturbed, utilized, or alienated from use by mining operations. But it is evident that they represent only one facet of the environmental problems associated with mining. In the following chapter emphasis will be placed on the influence that the mine site and the activities supporting its operation have on the surrounding environment, namely the 'shadow effect'.

Revegetation test plots on abandoned mine tailings, Sudbury, Ontario
I.B. Marshall, Environment Canada

Chapter Five

THE SHADOW EFFECT: BEYOND THE MINE SITE

MINING IMPACTS AND THEIR RELATIONSHIPS

THE NATURE OF MINING RESIDUALS

Every mining operation emits pollutants of various kinds and in varying quantities into the atmosphere and hydrosphere. The processes associated with the dispersion of residual contaminants (Table 36), are both numerous and complex. Moreover, these processes are both time- and space-dependent in that motion in the form of mass transfer, turbulance, and diffusion involves propagation velocities. While climatic and topographic factors are indispensable agents in controlling the dispersal of residual contaminants, the volume and type of emissions released are a function of the mineral characteristics of the ore to be mined, the processing methods employed, the spatial extent of the operation, and its volume of production. Figure 16 illustrates, in a simplified form, the processes interacting between the various mining phases and the environment.

LIMITATIONS TO PREDICTING ENVIRONMENTAL IMPACTS

There are a number of constraining factors which limit definitive statements on the quantitative effects and potential spatial extent of the environmental impacts from mining. The more important factors may be summarized briefly as follows:

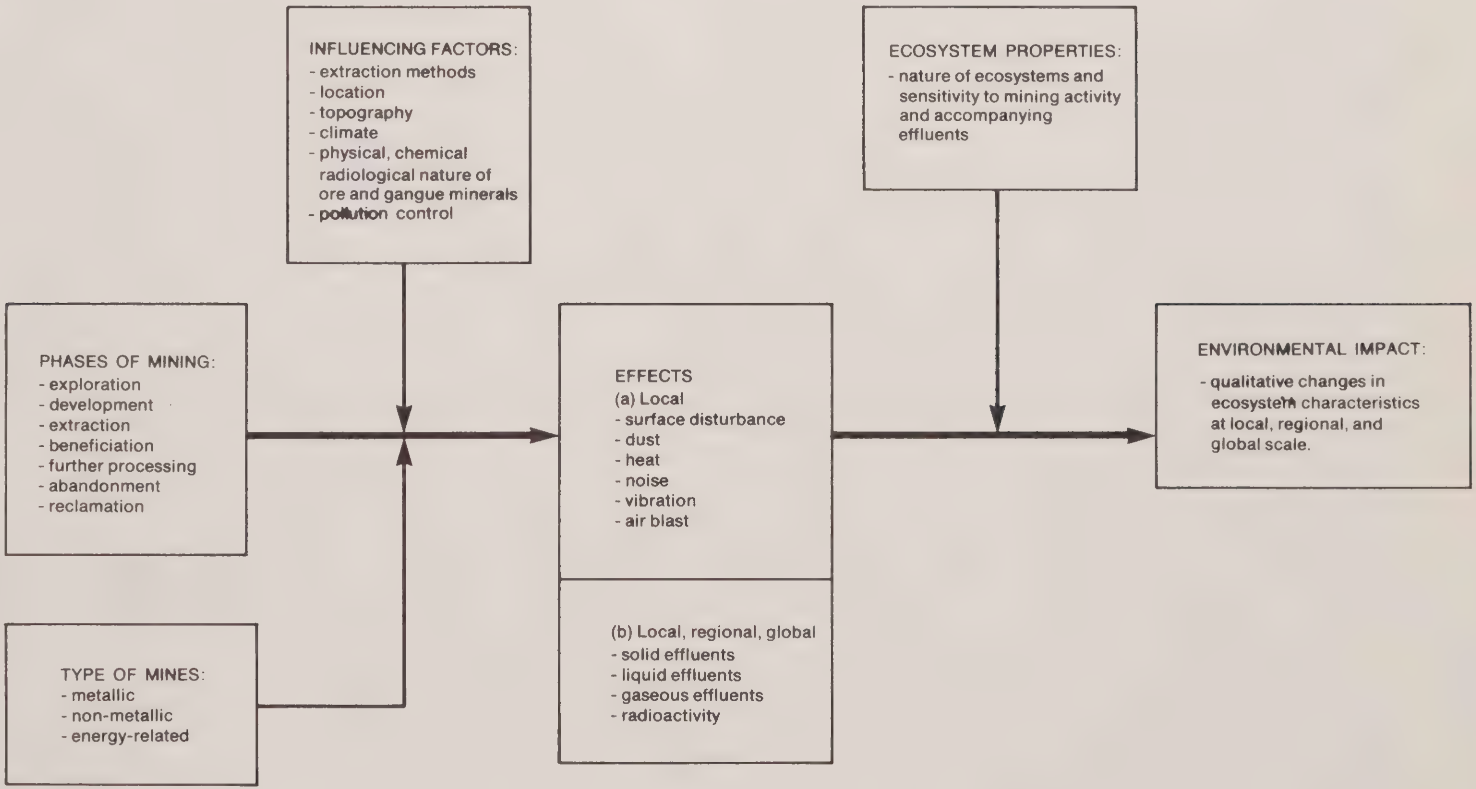
(i) Each mine is unique. Not only the physical, chemical, and radiological nature of ores and waste materials extraction and processing methods, but also location, topography, and climate influence the type and dispersal of environmental contaminants. The variability of these factors hinders any attempt to estimate potential impact either for the industry as a whole or even to operations involved in the extraction and processing of identical materials.

(ii) The proliferation of minerals extracted throughout Canada, the number of contaminants associated with each, and the variety of political jurisdictions has precluded, for the most part, comprehensive monitoring to provide quantitative information concerning the nature and extent of the environmental impact in the regional and global context. Moreover, the size and scope of a comprehensive monitoring program would undoubtedly be prohibitively expensive for either government or the mining industry. The difficulties are further compounded in that contaminants in liquid, solid, or gaseous form are released at each stage of mining activity, from the initial exploration phase to eventual abandonment. A multiplicity of variables within the extractive and beneficiation processes critically influences the transfer or dispersal of residuals to the environment.

(iii) The many varied contaminants released to the biosphere from mining activities modify ecosystem characteristics to a greater or lesser degree. The precise nature of the qualitative changes occurring in terrestrial and aquatic ecosystems, as well as the long-term effects on human health, remain largely unknown. Considerable additional research will be necessary to determine the broad area effects in diverse environmental conditions. As Ripley *et al.* (1978) observed: "... little is known

Abandoned gold mine, Carcross, Yukon
Territory NFB — Phototheque — ONF, Larry Weiseman

FIGURE 16. INTERACTION BETWEEN MINING PHASES AND THE ENVIRONMENT



Source: Ripley, et al; 1978

TABLE 36. BIOSPHERIC DISPERSION PROCESSES

<u>Atmospheric processes</u>
transport of vapour-phase material by wind
transport of particles by wind
vertical diffusion (important if there is a high altitude sink or low altitude transfer to other media)
fall-out and dry-deposition of particles
rain-out of particles
solution of vapour in the ocean
chemical changes such as photochemical oxidation and hydrolysis (both may depend on altitude and on the presence of other chemical species)
transport in ocean currents
vertical mixing and diffusion in upper layers
<u>Freshwater processes</u>
chemical transformations including precipitation and redissolution
absorption and desorption from suspended particles or sediments
transport on sediments
resuspension and transport of shallow water sediments such as occurs in estuaries or during storms
diffusion into sediments
evaporation from surfaces
distribution of water and its contaminants by irrigation can be locally important for predicting human exposure
uptake and metabolism by plants and animals
<u>Lithospheric processes</u>
diffusion into soil as vapour or in water solution
volatilization from soil by vapourization or by steam or wick distillation
volatilization from burning dumps, etc.
leaching into groundwater
absorption and desorption from soil particles
wind or water erosion of soil particles
metabolism by soil organisms
uptake by plants and animals
<u>Marine processes</u>
chemical transformations including precipitation and redissolution
absorption and desorption from suspended particles or sediments
sedimentation of suspended particles
resuspension and transport of shallow water sediments such as occurs in estuaries or during storms
diffusion into sediments
uptake and metabolism by plants and animals

Source: Mukammel, 1968.

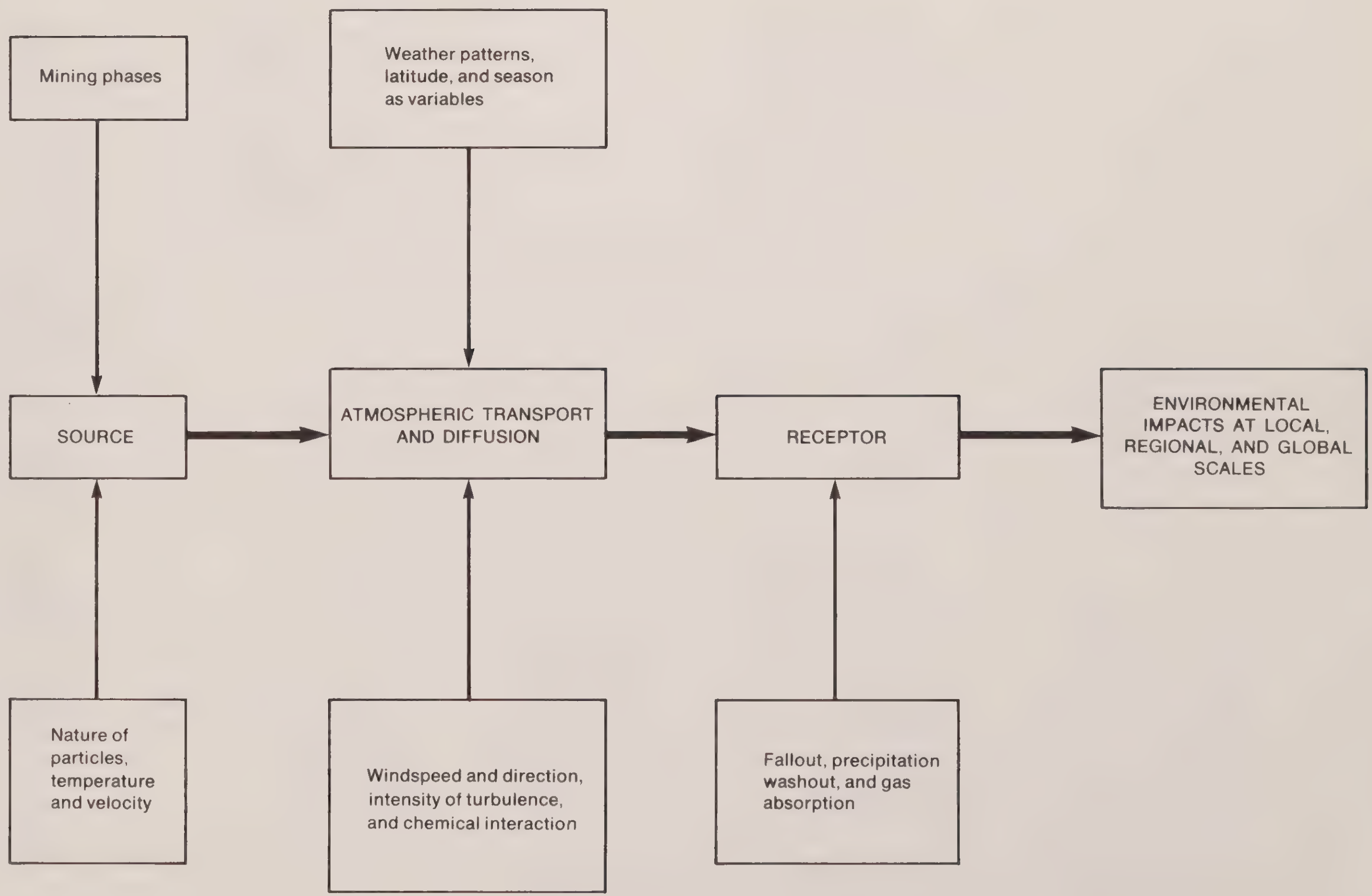
about the long-term effects and impacts of emission levels which fall below the threshold required for immediate visible damage to organisms''. Indeed, it appears that the greatest potential threats are those arising from the accumulating deposition of pollutants.

AIR POLLUTION

DISPERSION MECHANISMS

Atmospheric emissions, either liquid, solid, or gaseous, are dispersed primarily by the interrelated mechanisms associated with windspeed, vertical temperature, intensity of turbulence, and topography with wide variations

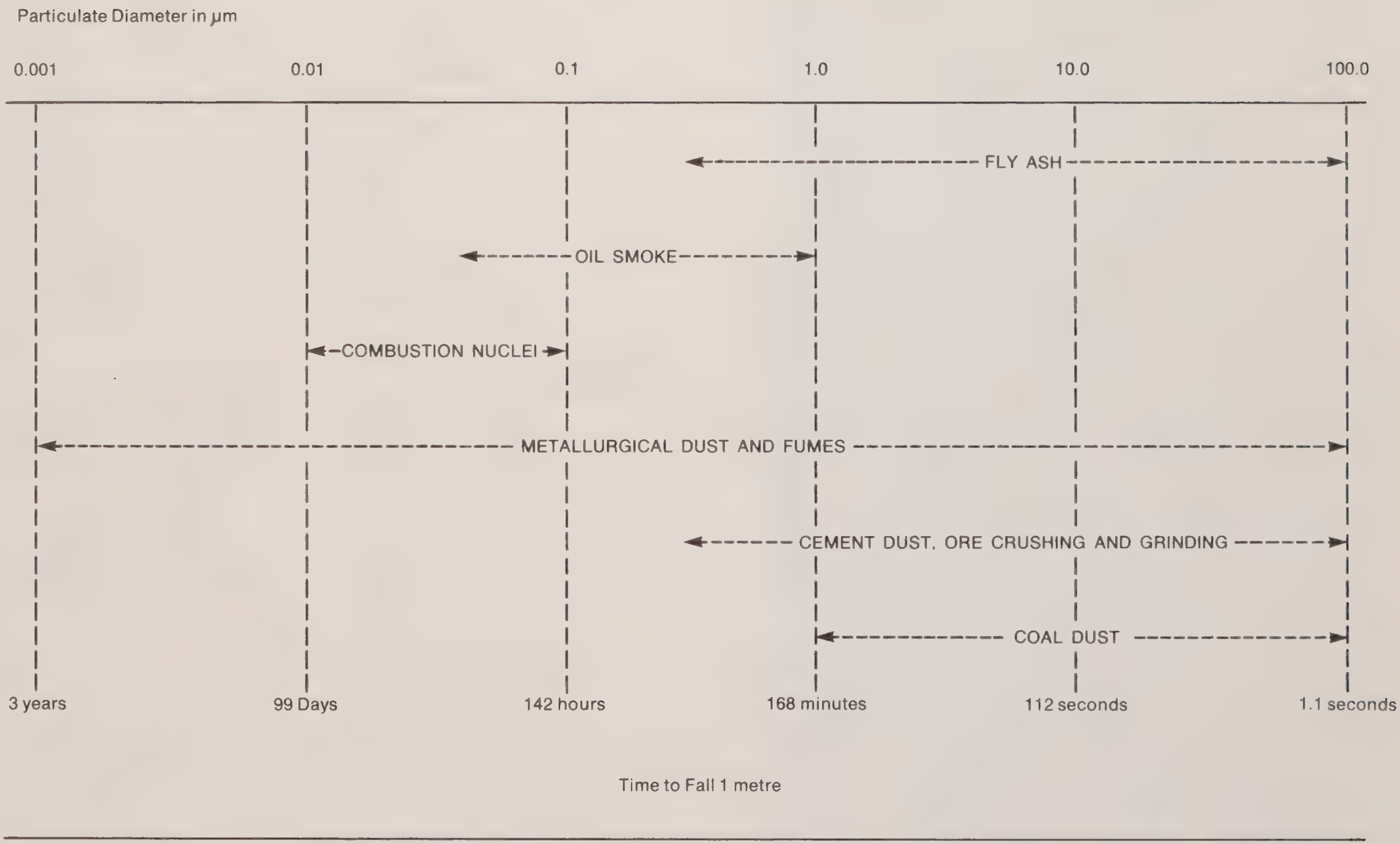
FIGURE 17. FLOW OF ATMOSPHERIC RESIDUALS



Land degradation caused by sulphur dioxide emissions, Sudbury region, Ontario.
NFB — Phototheque — ONF, Stan Sudol

in emission levels occurring in response to weather patterns, geographic latitude of operations, and season of the year (Figure 17). Contaminants may be transported in the direction of the prevailing winds or diffused both vertically and horizontally in the atmosphere. At certain periods throughout the year, atmospheric conditions (temperature inversions, for example) restrict ready dispersal and mixing, thus increasing the concentration of pollutants at ground level and adversely affecting air quality. Much of Canada appears to have a relatively high potential for air pollution, particularly the Mackenzie Valley region (spring months excepted), the Arctic, and Great Lakes region during the winter (Ripley *et al.*, 1978). The subjective assessment of the relative importance of a variety of atmospheric variables at the local, regional, and global scales of pollution is presented in Table 37. Clean air is composed of water vapour and gases (approximately 78 percent nitrogen, 12 percent oxygen, and small quantities of argon, carbon dioxide, and other gases) and contains minute suspended particles such as pollen, water, and snow droplets, etc. Many of man's activities, including mining, change the composition of air through the introduction of substances injurious to plants and animals and potentially dangerous to human health. The liquids and solids released to the atmosphere vary in size from several millimetres in diameter to less than 0.05 micrometres (1/1000th of a millimetre). Gravitational settling removes those particles larger than 10 millimetres which fall fairly rapidly within the vicinity of the original source. In contrast, smaller particles of less than one micrometre in diameter, termed aerosols, may be held in suspension in the atmosphere for years and be transported on a global scale (Figure 18). The eventual deposition of the smaller particles on the earth's surface is effected by the collection of the gaseous materials in raindrops, snowflakes, and cloud droplets which ultimately fall as precipitation. This process has been estimated to be responsible for the transfer and deposition of 86 percent of sulphur as sulphate aerosols and sulphur dioxide gas (Kellogg *et al.*, 1975). The composition of the particles released will vary depending upon the type of ore mined and the processing methods employed but, it will correspond closely to the characteristics of the ore mined.

FIGURE 18. TYPICAL SIZE RANGES OF ATMOSPHERIC PARTICULATE EMISSIONS WITH THEIR THEORETICAL FALL TIME (FROM STOKES' LAW)



Source: Ripley, et al; 1978

GENERALIZED EFFECTS OF AIR POLLUTION

In the context of smelter pollution near Sudbury, Ontario, Freedman and Hutchinson (1980) commented that ". . . despite the more efficient gravitational fallout of particulates, up to 60 percent of those emitted are carried beyond 60 kilometres. More than 97 percent of the emitted sulphur is carried beyond this distance".

Among the metals found in variable quantities around smelters and other processing operations are copper, iron, mercury, cobalt, arsenic, zinc, lead, and nickel. Although the long-term effects of airborne particles on ecosystems and human health remain to be firmly established, isolated studies have confirmed that the presence of metals beyond threshold limits do have deleterious effects upon plant life and human health. For example, Cannon (1960) noted the changes in plants which occurred as a result of the presence of heavy metals (Table 38), while other studies have detailed, in a limited way, the relative toxicity of various metals and their effects on human health (Table 39).

Certain metals, particularly lead (Ontario Ministry of Health, 1974; National Research Council, 1973; Rozousky, 1974), mercury, (Krenkel, 1974; Katz, 1972), and cadmium (Fiberg *et al.*, 1975) have already been extensively reviewed and shown to be injurious to human health. Further, a considerable number of studies have been undertaken to assess the nature and extent of damage by residual material for differing segments of the mining industry at a variety of locations. Examples are the effect on trees and soils of airborne salts from potash mining in Saskatchewan (Redmann *et al.*, 1979); a deterioration in forest quality as a result

TABLE 37. ESTIMATED SUBJECTIVE IMPORTANCE OF ATMOSPHERIC VARIABLES ON LOCAL, REGIONAL AND GLOBAL SCALES OF POLLUTION FOR SURFACE AND ELEVATED SOURCES

Atmospheric Variable	Local		Regional	Global
	Surface	Elevated	Surface and Elevated	Surface and Elevated
Wind near surface	1	2	3	5
Wind aloft	2	1	1	1
Horizontal wind variation	3	3	1	3
Atmospheric stability	1	2	4	5
Mixing height	3	3	2	3
Near-source aerodynamics	2	3	5	5
Surface characteristics	3	4	5	5
Topography	3	2	4	5
Precipitation (a)	1	1	1	1
Temperature and humidity (b)	4	4	3	2

(a) Particulates only.
(b) Substances involved in chemical transformation only.

(1) most important
(5) least important

Source: Johnson and Ruff, 1975.

TABLE 38. SYMPTOMS OF METAL TOXICITY IN PLANTS

Element	Effect
Aluminium	Stubby roots, leaf scorch, mottling.
Boron	Dark foliage; marginal scorch of older leaves at high concentrations; stunted, deformed, shortened internodes; creeping forms; heavy pubescence; increased gall production.
Chromium	Yellow leaves with green veins.
Cobalt	White, dead patches on leaves.
Copper	Dead patches on lower leaves from tips; purple stems, chlorotic leaves with green veins; stunted roots, creeping sterile forms in some species.
Iron	Stunted tops, thickened roots; cell division disturbed in algae, resulting cells greatly enlarged.
Manganese	Chlorotic leaves, stem and petiole lesions, curling and dead areas on leaf margins, distortion of laminae.
Molybdenum	Stunting, yellow-orange colouration.
Nickel	White, dead patches on leaves, apetalous sterile forms.
Uranium	Abnormal number of chromosomes in nuclei; unusually shaped fruits; sterile apetalous forms, stalked leaf rosette.
Zinc	Chlorotic leaves with green veins, white dwarfed forms; dead areas on leaf tips, roots stunted.

Source: Cannon, 1960.

TABLE 39. RELATIVE TOXICITY OF VARIOUS METALS AND THEIR EFFECTS ON HUMAN HEALTH

Metal	Toxicity	Effect on Human Health
Antimony	Similar properties to arsenic but much less toxic.	Long-term inhalation causes lung disease; skin irritation.
Arsenic	Toxic.	Several symptoms.
Beryllium	Toxic. Main hazard is inhalation of dust and its salts.	Symptoms may be delayed from 5 - 20 years.
Cadmium	Highly toxic.	Several symptoms.
Chromium	Metal: no hazards. Acids and salts are toxic.	 Ulceration and dermatitis.
Cobalt	Low toxicity.	Respiratory irritation and dermatitis.
Copper	Virtually non-toxic.	Unknown.
Iron	Pure iron: non-toxic.	None.
Lead	Toxic. Inhalation of lead fume and dust; ingestion.	Affects digestive, blood and nervous systems.
Manganese	Inhalation of excessive dust is toxic.	Affects nervous system.
Mercury	Toxic vapour or ingestion.	Affects nervous system, kidneys, eyes and skin.
Molybdenum	Low toxicity.	None. Some compounds cause irritation to respiratory tract and eyes.
Nickel	Metal and Salts: non-toxic. Nickel carbonyl: highly toxic.	None. Carcinogenic.
Thallium	Toxicity intermediate between lead and arsenic.	Retained by body leading to chronic poison symptoms.
Tungsten	Non-toxic.	None recorded.
Vanadium	Toxic.	Symptoms of chronic bronchitis; effects on lungs.

Source: Trevethick, 1973.

of sulphuric acid plant emissions at Kimberley in British Columbia (Hocking, 1974); and a wide variety of studies of vegetational damage arising from mining activities (primarily the smelting phase) in the Sudbury region of Ontario (Yohhan and Gorden, 1963; McGovern and Balsillie, 1973). Significantly, these studies have demonstrated that atmospheric pollutants are not confined to the immediate area of mining operations but may be dispersed over considerable distances depending upon prevailing winds and other climatic influences.

THE SULPHIDE ORE PROBLEM

By far the most important contributor to atmospheric emissions in Canada are the sulphide ores which comprise over 40 percent of ores mined, two-thirds of this total being extracted from 125 underground and open-pit operations in 1974 (Ripley *et al.*, 1978). Table 40 shows the composition of the common sulphide ores. Of the residual materials released to the environment, sulphur, with its conversion to sulphur dioxide in the processing stage, is the most significant in terms of quantities released and its potential shadow effects. It is estimated that more than 50 percent of total industrial emissions of sulphur oxides in Canada are attributable to the mining industry (Table 41).

The most-documented and oft-quoted example of the shadow effect is attributable to sulphide emissions from smelting operations in the Sudbury region of Ontario. Damage to vegetation by sulphur dioxide from the smelters has been detected over an area of 5,600 square kilometres with a central core area of more serious effects of 630 square kilometres (Dreisinger, 1970). Within this core area approximately 103 square kilometres were completely barren and a further 362 square kilometres semi-barren of vegetation (Winterhalder, 1978). Winterhalder observed that the history of denudation started with the early removal of larger trees for lumber, followed by smaller trees for pulpwood and roastbed fuel. Ground-level emissions of sul-

TABLE 40. COMPOSITION OF COMMON SULPHIDE ORES

Metal	Ore Mineral	Elemental Percentage					
		Cu	Ni	Pb	Zn	Fe	S
Copper	Chalcopyrite	35				30	35
Copper	Chalcocite	80					20
Nickel	Pentlandite		41			39	20
Lead	Galena			87			13
Zinc	Sphalerite				67		33
Iron	Pyrrhotite					62	38
Iron	Pyrite					47	53
Weighted mean[1]		9	3	6	18	28	36

[1] Based upon percentage.

Source: Ripley et al., 1978.

TABLE 41. AIR POLLUTANT EMISSIONS FOR SELECTED INDUSTRIES, CANADA, 1974

Emissions	Mining Annual Total	Percentage of Total Industry Emissions					
		Mining	Other Industries	Transportation	Stationary Fuel Combustion	Solid Waste Incineration	Miscel-laneous
	(Thousand Tonnes)	(%)	(%)	(%)	(%)	(%)	(%)
Particulates	1,209	50.7	10.2	3.4	14.2	1.4	20.1
Sulphur Oxides	3,473	56.3	18.9	1.5	23.3	-	-
Nitrogen Oxides	1.972	0.9	6.9	63.9	24.2	0.3	3.8
Hydrocarbons	3.542	0.1	5.8	52.8	5.9	1.2	34.2
Carbon Monoxide	518.5	3.4	5.2	70.5	1.1	2.3	17.5

Source: Environment Canada, 1979.

phur dioxide from open-pit roastbeds (pre-World War I), and subsequent stack emissions from smelters killed the remaining living vegetation nearby. Lesser effects of sulphur dioxide and heavy-metal contamination have also been detected over a much greater area. Over 1,000 square kilometres have been seriously affected by heavy metals and the productivity of 1,460 square kilometres of forest potentially prejudiced by sulphur dioxide. (Hutchinson and Whitby, 1974). Recent investigations (Freedman and Hutchinson, 1980) have shown that, although there have been reductions in sulphur pollution in the Sudbury area that have allowed some re-establishment of vegetation, there remains a severe regional problem of acid precipitation. High levels of nickel and copper within 30 kilometres of the 380-metre super smokestack at Coppercliff have been sufficient to inhibit root growth and the establishment of seedlings of many species.

Similarly, sulphur dioxide emitted from the iron-ore sintering plant at Wawa, Ontario adversely affected forest productivity on 108,000 hectares (Rabbitts *et al.*, 1971). A study of the area by Gordon and Graham in 1963 traced noticeable damage to a distance of 30 kilometres and severe damage to 20 kilometres downwind. Thirteen years later a LANDSAT imagery study confirmed that the areas originally delineated were still affected (Murtha, 1974). About 45 percent of Canada's total sulphur emissions are concentrated in the non-ferrous smelting sectors of the mining industry, (Environment Canada, 1979*a*). The effects of sulphur emissions on the off-site areas illustrated above represent the shadow effect at its most extreme. Sudbury is the single largest source of sulphur dioxide emissions in the world (Summers and Whelpdale, 1976) and is responsible for fully 20 percent of Canada' sulphur emissions (Altshuller and McBean, 1979).

The effects of sulphur dioxide emissions in the global context have been a source of mounting concern in recent years. The problem was considered to be sufficiently serious to warrant the establishment, in 1978, of the United States-Canada Research Consultation Group (RCG) on the Long-Range Transport of Air Pollutants (LRTAP) to aid in the co-ordination of research studies and to exchange scientific information on the subject of LRTAP and related acid precipitation (Altshuller and McBean, 1979). The case study which follows is taken from the initial report of the RCG and details the accumulating and widespread effects of acid precipitation in North America.

Land degradation caused by sulphur dioxide, Sudbury, Ontario
NFB — Phototheque — ONF, Stan Sudol

Bag filter system for pollution control
NFB — Phototheque — ONF, Richard Pierre

Case study: Long-Range Transportation of Air Pollutants

In its Preliminary Overview, the Research Consultation Group on the Long-Range Transport of Air Pollutants identified acid precipitation as the problem of greatest concern with sulphur-dioxide emissions contributing approximately two-thirds of the acidity in precipitation and nitrogen oxides about one-third. The problem is further aggravated by the trans-boundary movement of sulphur compounds between the United States and Canada. It was estimated that three to four times as much sulphur is transported from sources in the United States as in the opposite direction. Further, it identified the smelting industry as the major source of sulphur emissions in Canada whereas, in the United States, the greater majority of sulphur emissions originate from power generation. Future trends indicate that sulphur-dioxide emissions will increase at a modest rate while nitrogen-oxide emissions will increase significantly in response to expanded output in the electric-utility sector and other combustion sources. Extrapolation of current pollution trends would appear to confirm that nitric acid will be a significant contributor to acidification in the United States in the future. Significant quantities of this pollutant will be transported to and deposited in Canada.

While the report noted that the long-range transport of residual contaminants is below the levels which affect the ecosystem in an immediate and acute way, synergistic effects associated with long-term accumulation of polluting elements, or "loading" of materials in combination, are the major factors contributing to increasing environmental degradation. Unfortunately, the problem of accumulation and its effects upon other land resources had only recently received international attention and very little is known, as yet, about the longer-term implications of cumulative loading on ecosystem characteristics.

Accumulating evidence suggests that acid precipitation is contributing to substantial and widespread deterioration in the health of biospheric ecosystems as well as affecting the human welfare. The following observations derived from the preliminary report serve to indicate the potential severity and increasing spatial extent of the acidification problem:

(i) Documented declines in the success of Atlantic salmon spawning are due to acidification effects in streams in Quebec and Nova Scotia.

(ii) Lakes in the Haliburton-Muskoka region of south-central Ontario have been deprived of 40 to 75 percent of their neutralizing capacity in a ten-year period or less.

(iii) A sequence of decline in valued sport fishing has been documented in lake studies in Ontario. Similar studies undertaken in the Adirondack Mountain region of New York State estimate that acidification of numerous lakes has resulted in an annual economic loss of $1 million from tourism.

(iv) Currently, 140 lakes in the Sudbury region of Ontario have become acidified, with thousands of lakes in eastern Canada showing the initial symptoms of acidification.

(v) Extinction of the rare Aurora brook trout in Ontario is seen as a consequence of pH depression in its habitat.

(vi) Elevated concentrations of aluminum, manganese, zinc, cadmium, lead, copper, and nickel have frequently been observed in acidified lakes. The resulting physiological stress on aquatic organism remains, for the most part, unknown.

(vii) Excessive acidity has been demonstrated to adversely effect the germination of conifer and hardwood seeds.

(viii) A decline has been observed in forest growth in the north-eastern United States although it is not currently possible to ascribe the decline exclusively to acidification effects. However, depositions of similar magnitude to those occurring in North America have been extensively monitored in Scandinavia and have been shown to result in severe environmental degradation of the forestry resource. Clearly, a reduction in forest productivity would have profound long-term repercussions on the Canadian economy.
Rather than delay prompt remedial action pending indisputable evidence, the report suggests that ways of slowing the future rate of degradation be identified quickly before the situation becomes irreversible.

(ix) A number of isolated experiments performed upon a variety of agricultural crops have confirmed that acid precipitation promotes a decline in crop yield. The findings have stimulated an extensive screening of virtually every field crop by the United States Environmental Protection Agency to determine their sensitivity to simulated acidification.

(x) The magnitude of sulphur emissions currently being deposited by long-range transport is

only slightly less than that required to cause a substantial deterioration in soil quality.

Source: Altschuller and McBean, 1979.

In the light of the recent evidence, the dispersal of atmospheric pollutants on a global scale is of sufficient and increasing severity to warrant, not merely concern, but concerted remedial action notwithstanding the current limitations in our knowledge of cause and effects. The cumulative effects of airborne contaminants on aquatic and terrestrial ecosystems may have considerable long-term repercussions on the future viability of the fishery resources, the land, and its associated agriculture, forestry, wildlife, and recreation resources. A decline in productivity of these resources may incur, amongst others incalculable economic losses.

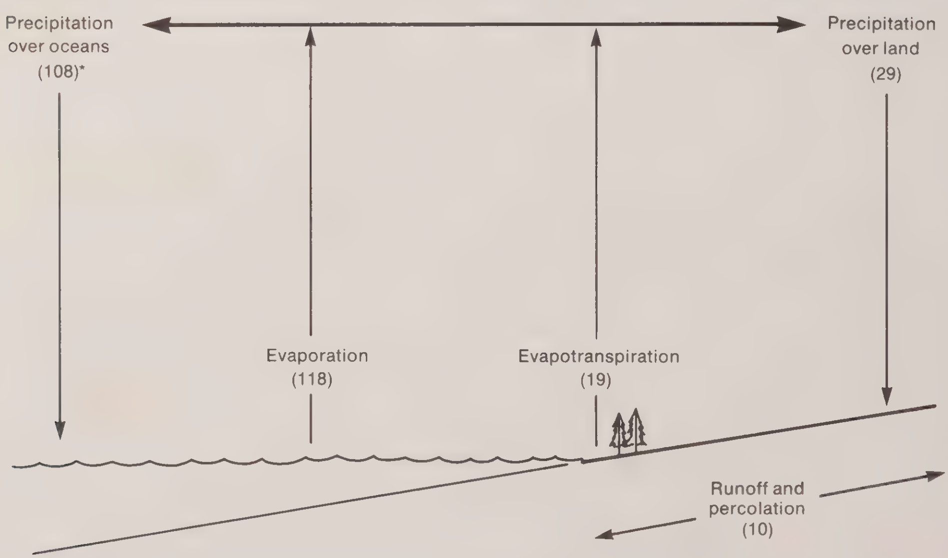
WATER POLLUTION

DISPERSION MECHANISMS

The dispersal of mining residuals to the hydrosphere is a much more complex process than those released to the atmosphere. Gravity dominates the process, relentlessly drawing all water and its accompanying substances to the lowest possible level. This process is temporarily interrupted by evaporation, in which water converted to water vapour is purified of its contaminants. As water vapour disperses into the atmosphere, it cools, reverts to its liquid form, and eventually returns to the earth's surface as rain or snow. In its reversion to a liquid, water once again accumulates impurities which, upon falling, are exchanged with those of the surface environment. These processes are part of the hydrological cycle (Figure 19).

Both mass flow, as demonstrated by a flowing stream and diffusion, act to disperse residuals in the hydrosphere. Even waters which might appear to be motionless are subject to currents and turbulence in response to inflows and outflows of water. These processes, together with atmospherically-induced wave action, promote continuous mixing of the water and the dissolved and suspended materials within it. As in the

FIGURE 19. GENERALIZED ILLUSTRATION OF WORLD HYDROLOGICAL CYCLE

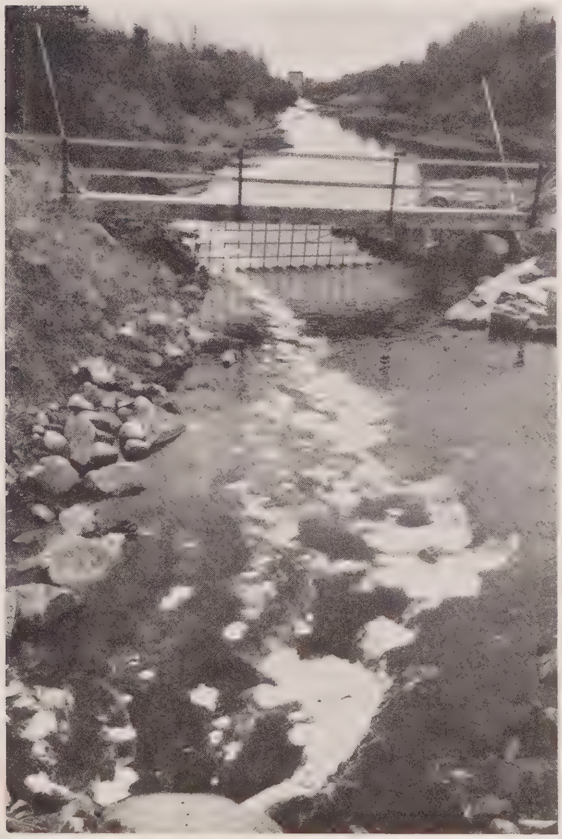


*Figures in brackets are 10^{15} gallons/year

Source: Lvovitch, 1972

atmosphere, the transport of heavier materials in water is limited by gravitational forces which cause them to be deposited closer to their points of origin. In contrast, dissolved materials and smaller colloidal particles in suspension disperse more readily and are capable of being transported over considerable distances to effect water quality at the regional scale.

Unlike the composition of the atmosphere which is relatively homogeneous, natural surface waters display marked variations in their content of dissolved and suspended materials. Studies in the USA have revealed that dissolved solids can be present in surface waters from the microgram (ppb) range to in excess of 900 milligrams per litre (Durum, 1971). The hydrosphere further differs from the atmosphere in its capability to support myriad forms of life which are immediately susceptible to toxic elements released into surface waters.



Polluted mine water. Sudbury, Ontario
NFB — Phototheque — ONF, Kryn Taconis

WATER USE AND POLLUTION IN THE MINING PROCESS

Substantial quantities of water are used by the mining industry (Figure 20). The potential for the release of polluted water into the environment is present in all phases of mining.

The removal of minerals by a high-velocity jet of water is known as hydraulic mining. Presently it is practised at one underground coal mine in Canada. It has also been used to remove unwanted overburden in the recovery of gold and mineral aggregates, but unfortunately the remaining sedimentary material has the potential for seriously silting local watercourses, depending upon the method of disposal. Water is also used to suppress dust (for the workers' health), for cooling drills, and as 'washdown' water in mines.

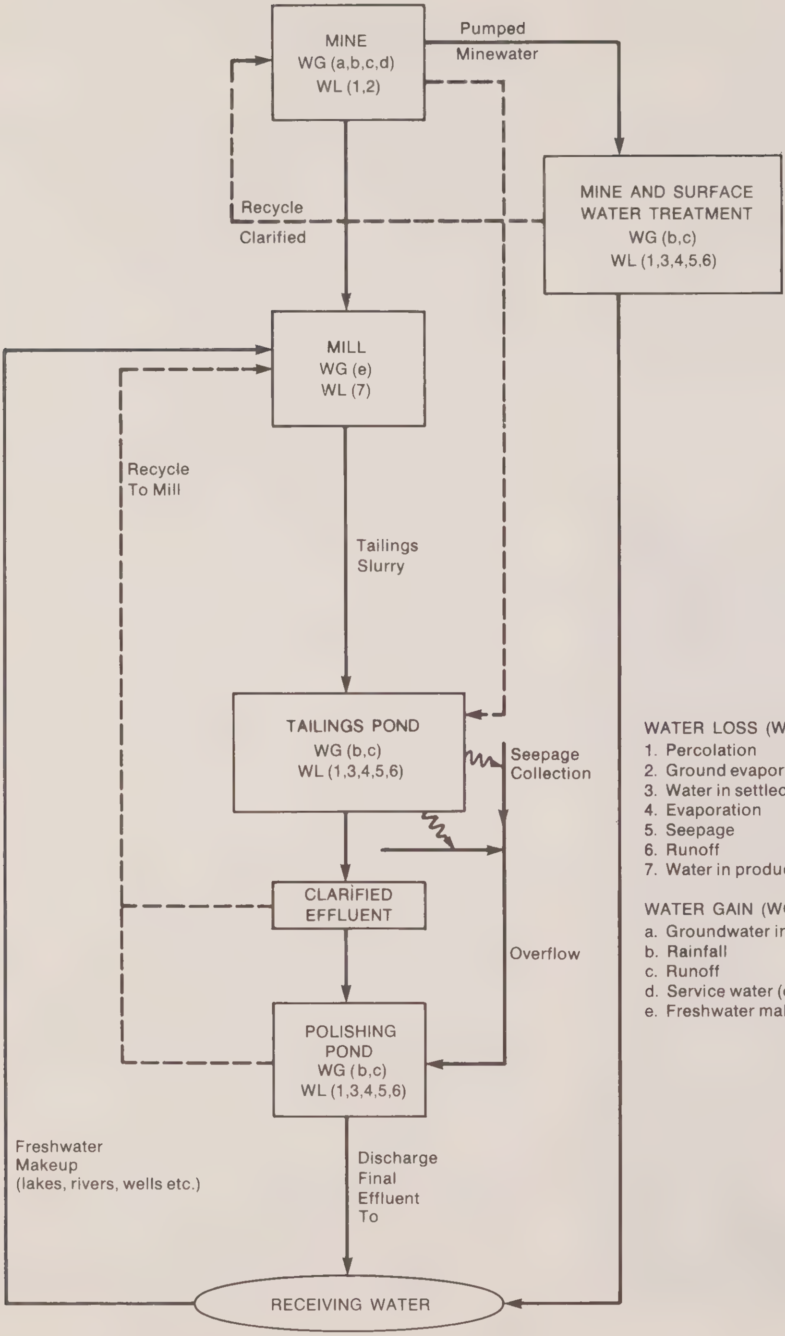
More water is used in the beneficiation processes than in any other phase of mining. Down and Stocks (1977) estimated that beneficiation processes in the mining industry consume 79 percent of all water used for mining purposes. Examples of water use at selected mine sites are given in Table 42. As process water is in contact with the raw mineral during the beneficiation stage, the potential for chemical and physical contamination is relatively high. Upon release, process water typically contains small quantities of reagents, residuals of the original material, and other waste minerals together with their dissolved chemical constituents. Depending upon disposal methods, some or all of these residuals may be released to the environment.

Water is commonly used as a slurrying medium to transport crude ores for treatment, to transport minerals through the beneficiation processes, and to dispose of waste materials. Over shorter distances, a partial, or totally closed, transportation system may be installed to avoid the discharge of contaminated waste water into the environment. Where longer distances are involved, however, the capital costs of constructing a totally closed system may be prohibitively expensive. Consequently, considerable quantities of waste water may be released which will contaminate both surface and groundwater.

Service water is primarily used for cooling equipment (bearings, pumps, compressors, etc.), lubrication, air conditioning, and dust suppression. Although the quantity of water used is relatively insignificant, it may be discharged at a sufficiently high temperature to adversely effect aquatic life.

Polluted water from mining activities is primarily associated with mine drainage, mill water, and waste

FIGURE 20. GENERALIZED WATER USE FLOWSHEET FOR A METAL MINE



WATER LOSS (WL)
1. Percolation
2. Ground evaporation
3. Water in settled solids to waste
4. Evaporation
5. Seepage
6. Runoff
7. Water in product

WATER GAIN (WG)
a. Groundwater inflows
b. Rainfall
c. Runoff
d. Service water (e.g. dust suppression, drilling etc.)
e. Freshwater makeup

Adapted from: Scott and Bragg, 1975; Hawley, 1977; and Down and Stocks, 1977.

TABLE 42. WATER USE AT SELECTED MINE SITES

Size of Mine Tons/Day	Mine Type	Tons/Day Milled	Precipitation (inches)	Water used in Milling Process: gallons per day/ 1000 T/D	Water used in Milling Process: gal/year* (millions)	% Reused (reclaim water)
			DRY CLIMATE			
Large, 72,000	Cu, Mo	25,000	10-15	14,400,000	5,040.0	83
Large, 19,000	Cu	6,500	15-20	2,152,800	753.4	80
Small, 750	Cu, Ag, Au	500	15	475,000	166.3	94
			MODERATE CLIMATE			
Large, 48,000	Cu, Mo	24,000	20	16,930,000	5,927.0	87
Large, 18,000	Coal	12,900	41	11,330,000	3,965.9	100
Small, 1,700	Pb, Zn	700	30	282,000	98.7	0
Small, 600	Mo	600	29	142,000	49.8	70
			WET CLIMATE			
Large, 13,000	Fe	6,500	120	1,300,000	458.6	0
Large, 3,000	Cu	3,000	60	2,720,000	952.5	0
Small, 1,400	Ag, Pb, Zn	1,000	60-100	750,000	262.0	0
Small, 800	Cu, Fe	800	60-100	126,000	44.5	0
Small 250	Mo	215	90-110	92,000	32.5	0

* Based on 350 day operating year.

Source: Mining Association of British Columbia, 1972.

solutions released in the hydro and electro-metallurgical processes.

WATER POLLUTION IN THE EXTRACTION PHASE

During underground operations, exposed material within the mine oxidizes and gives rise to acid production which contaminates the water. The most common case is the exposure of a sulphide to air and water which promotes a chemical reaction resulting in the formation of sulphuric acid. Problems of acid mine drainage are predominantly chemical and extremely complex, and originate with the extraction of sulphide minerals. Many reactions are possible depending upon the environmental conditions existing in the mine and the nature of other minerals which may be present. Not all mines have acid mine-drainage problems. In Canada, it is normally associated with sulphide-bearing metallic ores, for example pyrite, pyrrhotite, chalcopyrite, sphalerite, marcasite, arsenopyrite etc., or coal found in the Maritime provinces.

Acid contamination is increased by water entering the mine from external sources. In addition to seepage from natural watercourses, which constitutes the larger part of the external supply, water (usually one-third by weight) may be used to transport mill tailings underground for the purposes of backfilling excavations and

TABLE 43. SOME DETAILS ON THE EFFECTS OF MINING POLLUTION ON AQUATIC ECOSYSTEMS IN CANADA

Locality	Source of Pollution	Chemical Effects	Biological Effects
New Brunswick			
S. Tomogonops R. & N.W. Miramichi R.	Heath Steele	Heavy metals, increased hardness acid generation.	Decline in *Salmo salar* since 1965; reduced diversity and abundance of benthos.
Nepisiguit R.	Brunswick 6	Heavy metals	*Salmo salar* fishery approaching zero.
Ontario			
Crowe R. Basin	Bancroft area mines	TDS, $SO_4^{=}$ and hardness increased 8-10x ^{4} in Bow L.	Aquatic biota affected only in immediate vicinity of tailings decant.
Serpent R. Basin	Elliot L. area mines	Acid, high TDS,$SO_4^{=}$, NO_3^- and Ca^{++}. Most affected were Quirke L. & Pecors L. Biological effects mainly because of acidity.	Reduced productivity, altered phytoplankton and and zooplankton communities. Elimination of *Stizostedion vitreum* & reduction of *Salvelinus namaycush.* Reduced benthos diversity.
LaCloche Mnt. lakes	Sudbury smelters	Increased acidity from aerial fallout.	Extinction of fish populations.
Manitouwadge L. area	Noranda & Willroy mines	Acidity, toxic concentration of NH_3, zinc, copper, iron; nutrient enrichment; high TDS especially $SO_4^{=}$. Mose, L. has become meromictic - O_2 deoxygenated below 20 feet.	Mose, L. total elimintaion of macroinvertebrates; reduced benthos in all lakes.
Manitoba			
Bernic L.	Tantalum Mining Co.	Slight increase in turbidity, TDS & Suspended solids.	Decrease in abundance and diversity of benthos.
Borden L., Clarke L. & Lily L.	Mannibridge	No effect	No effect
Grass R.	INCO, Thompson	Increased turbidity, hardness, TDS, copper and chloride.	Reduced benthos, and absence of of Ephemeroptera in a small area.
Ospwagan Lakes	INCO, Thompson	Overburden into Upper Ospwagan L. Increase of most parameters in Lower Ospwagan L.	Major reduction in Amphipoda & Emphemeroptera in 1968, but recovering in 1969.
Schist L.	Flin Flon Mines	Increased turbidity, siltation, CO_2 and metals. Pollution spreading into L. Athapapuskow.	Sparse benthos, entirely of chronomids. No *Stizostedion vitreum* or *Salvelinus namaycush* in affected area. Decrease angling success.
Eldon R. & Cockeram L.	Lynn Lake	Siltation; toxic amounts of heavy metals, especially cadmium.	Decrease in fish and benthos populations. Fish and benthos absent from area receiving drainage.
British Columbia			
Pend d'Oreille R.	Reeves MacDonald	Increased turbidity and siltation.	Benthos severely reduced, fewer aquatic plants indicating reduced 1° productivity.
Benson L.	Coast Copper	Increased turbidity; has become meromictic.	No benthos; fish population probably reduced.

Source: Clarke, 1974.

for processing and servicing needs. The average composition of underground drainage waters has been calculated at 51 percent from natural watercourses, 14 percent from mine backfill (where employed), 34 percent from service and process sources, and the remaining one percent from other unspecified sources (Scott and Bragg, 1975*b*).

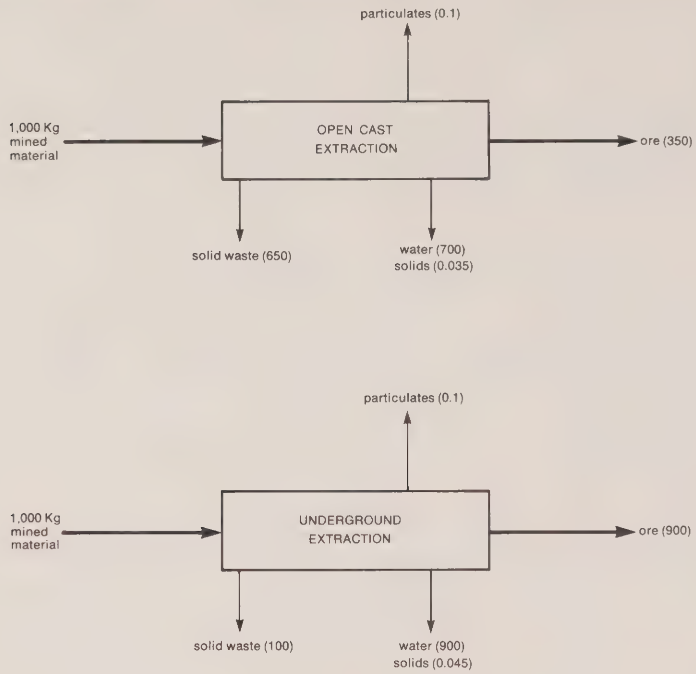
As the total average water flow into an underground mine is estimated at 1,000 litres per minute, pumping must be maintained to ensure continuous operation. The estimated flow is an average for the industry and is subject to wide variations between mines and over time in any particular mine. Following pumping, the drainage water, which frequently contains significant quantities of highly toxic dissolved minerals, is impounded at the surface prior to discharge and recycling. The impoundment areas may range from small ponds accepting a few tonnes per day to large tailings dams enclosing several square kilometres and receiving slurry wastes at the rate of thousands of tonnes per day. A sequential approach to water clarification is normally employed and involves the use of a single

TABLE 44. TYPICAL ASSAYS OF ACID WATERS IN CANADA
(All Concentrations are mg/l except pH)

Type of Operation	Cu - Pb - Zn (Mine and Surface Drainage)	Cu - PB - Zn (Mine Water)	Uranium (Seepage)	Cu - Zn (Active Mine)	Base Metal (Abandoned)	Uranium (Abandoned Mine)
pH	4.0	2.0	2.0	3.0	2.6	2.0 - 2.8
Suspended Solids	8.8	690	Nil	-	-	25
Total less solids	79	24,000	-	-	9,200	13,440
Hardness	293	2,960	-	-	1,390	
Ca	-	-	416	-	454	-
Mg	-	-	106	-	178	-
Cu	17	11	3.6	0.0	2.5	2.2
Zn	118	1,090	11.4	0.4	34	9.4
Pb	0.4	58	0.7	0.11	0.5	-
Fe(total)	79	1,830	3,200	11.7	1,300	300
Mn	21	0	5.6	0.4	8.2	3.6
SO_4	36	16,560	7,440	885	4,050	6,900
COD	-	245	270	-	110	-

Source: Scott and Bragg, 1975.

FIGURE 21. TYPICAL MATERIALS FLOW FOR OPEN PIT AND UNDERGROUND MINES (Measured in Kg per 1000 Kg of mined material)



Source: Ripley, et al. 1978

pond, or a series, to allow the settling out of the contained solids. The effluent is then subject to additional treatment to neutralize acids and remove heavy metals and radioactive wastes.

During impoundment, the effluent is partially depleted through seepage, percolation, runoff, and evaporation. The effect on the environment of water losses is dependent, to a large degree, upon the location of the mine within the localized drainage basin and its interconnecting watercourses. The nature of the materials discharged can also effect the environment profoundly. The heavier particulate matter in suspension will fall out under gravity relatively close to the point of discharge. Dissolved metals, on the other hand, are capable of being transported over much greater distances and can effect water quality at the regional scale.

Table 43 illustrates the effects of mining pollution on aquatic ecosystems in Canada. Together with Table 44, the values listed demonstrate the adverse effects of acid mine drainage, lowered pH values which eliminate aquatic organisms, and increased levels of acidity, sulphate iron, and total solids.

As in underground mines, surface operations (both open-pit and strip) are also prone to the effects of acid mine drainage. While the mean flow of water into an underground mine is approximately 1,000 litres per minute, for open-pit mining the mean value is 13,800 litres per minute, derived 48 percent from natural watercourse, 9 percent from service and process, water and 13 percent from other sources (Ripley *et al.*, 1978). Figure 21 illustrates a typical materials flow for open-pit and underground mines. Clearly, the substantial quantities of water involved in surface mining operations enhance the potential for effluents to enter the natural environment. The problem is compounded by the run-off, leaching, and percolation processes acting upon the residuals contained in the solid wastes which are considerably in excess of those produced in underground operations. For example, the extent to which a

new, large-scale, coal strip mine can affect the ground water, surface run-off, and sedimentation effects has been illustrated in the findings of the International Joint Commission, Poplar River Water Quality Study (1979) presented in the following case study.

Case Study: Poplar River Water Quality, Saskatchewan

The new strip mine in the Cornach area of South East Saskatchewan will disrupt a total of 41.8 square kilometres on either side of Grand Creek, affecting eight distinct drainage areas ranging in size from 2.9 to 29 square kilometres during the 35-year life of the project. The lignite seam being mined is an aquifer with additional aquifers present in the overburden. To overcome this problem, ground water is to be lowered with perimeter pumping wells to prevent water flowing into the pits. Approximately 11,300 cubic metres per day will be withdrawn from the water table and discharged to the surface water system. The volume pumped is expected to decrease over several years, due to stabilization of the ground-water depression cone.

Ground-water seepage, direct precipitation, and run-off from adjacent unreclaimed spoil piles which accumulate as mine water, is to be pumped as required from sumps to a holding point prior to discharge into the local watershed. Expected annual precipitation to be caught in each excavated pit is approximately 373 millimetres, of which an estimated 20 percent of the precipitation will be retained in the sumps, for an annual volume of 74,600 cubic metres. Average seepage in flow is estimated to be 598,000 cubic metres thus the combined annual discharge to the surface-water system will be approximately 672,000 cubic metres. To date, the quality of the water is still not well characterized.

Post-mining run-off will increase dramatically from the reclaimed surface. A multiplier of four times the pre-mining rate was used to estimate post-mining run-off from reclaimed areas. This increase is estimated to decrease at a linear rate of decay such that pre-mining rates are attained in the seventh year after reclamation commences. Annual run-off from the total mine area is estimated to peak at approximately 1,900,000 cubic metres in 1990, an increase of nearly 35 percent over pre-mining annual run-off volumes.

Post-mining sediment yield likewise is expected to increase significantly from the reclaimed surface. A multiplier of ten times the pre-mining rate was used to estimate post-mining sediment yield. This increase is expected to decrease at a near-linear rate such that pre-mining rates are attained in the seventh year after the commencement of reclamation.

Annual sediment yield from the total mine area is estimated to peak at approximately 5,720 cubic metres in the year 2014, an increase of 39 percent over pre-mining annual sediment yields. Actual sediment yields may, however, be substantially greater than those estimated here.

Since there is insufficient data and knowledge to predict the exact long-term effects that the increased surface run-off and sedimentation will have, it is anticipated that mine water and surface run-off will have to be monitored, and if necessary, impounded or otherwise treated in order to meet the provincial water-quality standards.

Source: International Joint Commission, 1979.

Residual metals from mining operations vary substantially in their toxic effects on living organisms and are present in all production stages of mining. In comparative studies undertaken to determine the relative toxicities of heavy metals to algae (Hutchinson, 1973), silver was found to be the most toxic metal in its capability to retard the growth of chorella (a common green algae) at levels of 0.005 parts per million. Also highly toxic were cadmium, copper, and mercury followed by the less-toxic selenium and nickel. Of the elements studied, cobalt, barium, and lead were the least toxic. Depending upon the metal concentration involved, the algal response was either a gradual retardation of growth or dramatic reduction beyond a certain threshold level. Table 45 represents a classification of some chemical elements according to their potential toxicity. Of concern is the accumulation of toxic substances in food chains. Residual metals entering aquatic systems may undergo conversion by natural biological processes, for example, the transformation of mercury to a poisonous neutrotoxin, methyl-mercury. This compound increases at a rate faster than it can be degraded by other organisms and, in consequence, accumulates in host tissue, fish, for example. Chemical conversions similar to that of mercury occur in the cycling of other elements and it is possible to predict the other heavy metals which may be transformed in a similar way.

"It is evident that with evolution of such a dynamic system of biological cycles for the toxic elements, small disturbances in these cycles will affect the natural equilibriums which will in turn affect the concentrations of toxic intermediates. Great care must therefore be taken in deciding which species of toxic element should be monitored in the envi-

TABLE 45. CLASSIFICATION OF SOME ELEMENTS ACCORDING TO THEIR POTENTIAL TOXICITY

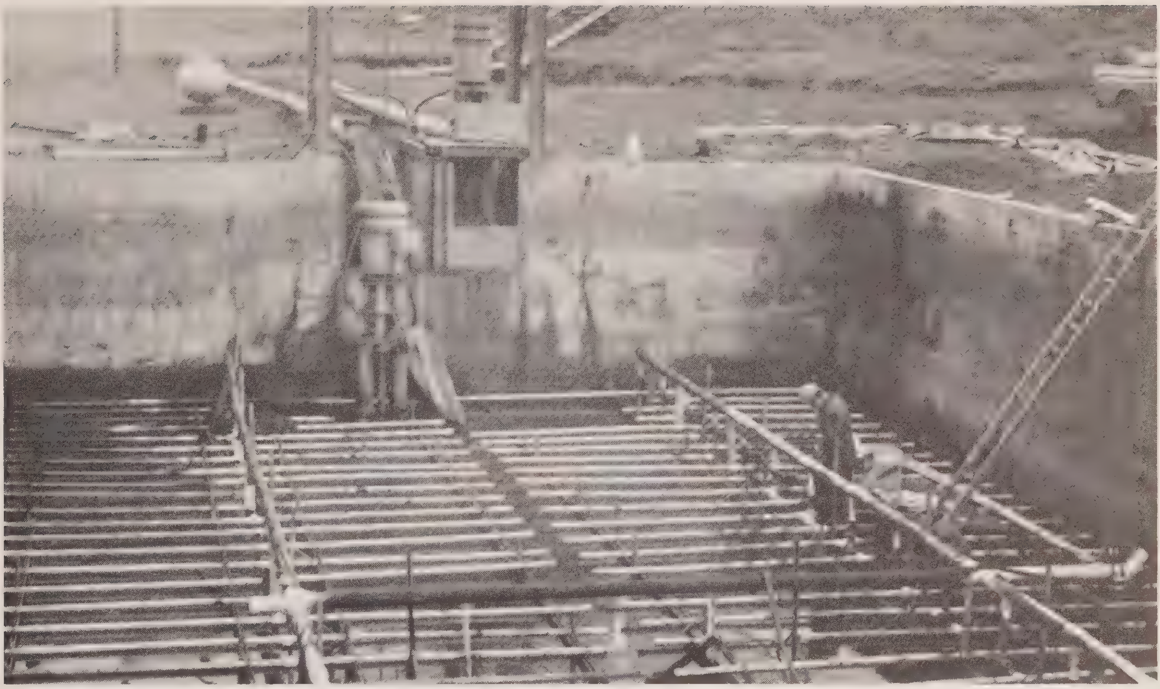
Non-critical	Very toxic and relatively accessible	Toxic but very insoluble or very rare
Sodium	Beryllium	Tatanium
Potassium	Cobalt	Hafnium
Magnesium	Nickel	Zirconium
Calcium	Copper	Tungsten
Hydrogen	Zinc	Tantalum
Oxygen	Tin	Rhenium
Nitrogen	Arsenic	Gallium
Carbon	Scandium	Lanthanum
Phosphorus	Tellurium	Osmium
Iron	Palladium	Rhodium
Sulphur	Silver	Iridium
Chlorine	Cadmium	Ruthenium
Bromine	Platinum	Barium
Fluorine	Gold	
Lithium	Mercury	
Rubidium	Thallium	
Strontium	Lead	
Aluminum	Antimony	
Silicon	Bismuth	

Source: Wood, 1974.

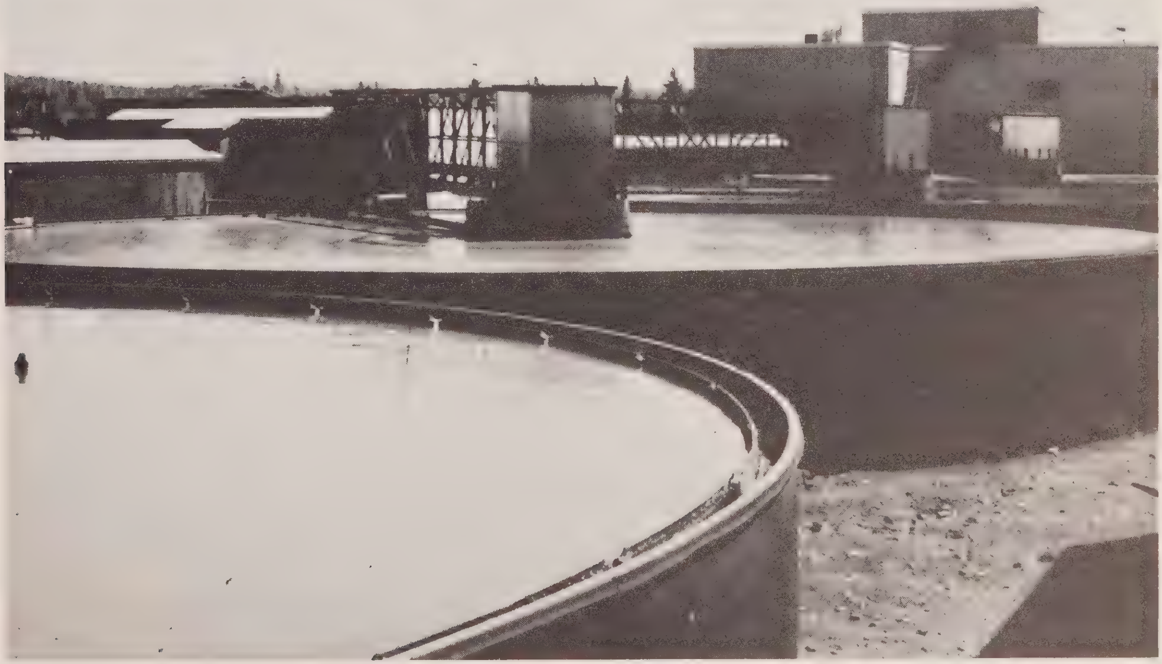
ronment, because neglect of these biological transformations can make the development of models for the flow of chemicals through the environment a futile exercise." (Wood, 1974).

The discharge of polluted water from mining activities can adversely affect man as well as other organisms. While trace elements in minute quantities are essential for human health, their presence in quantities beyond certain, and largely unknown, thresholds may have disastrous effects. Perhaps the best-known example is that of cadmium-polluted water discharged from a lead/zinc/cadmium mine in Toyama Prefecture, Japan. Cadmium-polluted water was used for irrigation purposes in paddy fields close to the site of mining operations. Human ingestion of cadmium through the consumption of rice resulted in numerous cases of 'itai-itai' disease, one of the symptoms of which was severe degeneration of the bones to the extent that even coughing was sufficient to cause the fracture of ribs. Between 1946 and 1965, nearly 100 deaths were attributed to the disease.

This example is, of course, an extreme case, occurring in a densely populated and land-scarce country where conflicts between the mineral extraction industry and other resources needs are more likely to occur. In contrast, the extraction of potentially toxic materials in Canada is generally confined to areas located at some distance from population centres. Nevertheless, the potential for toxic substances to enter the food chain and to be subsequently ingested by human beings does exist. The radioactive elements associated with uranium mining, for example, have occasioned public concern recently over the adequacy of the treatment of toxic effluents discharged with the waste water. The relatively long-term monitoring of waste-control methods in uranium mining in northern Ontario has revealed

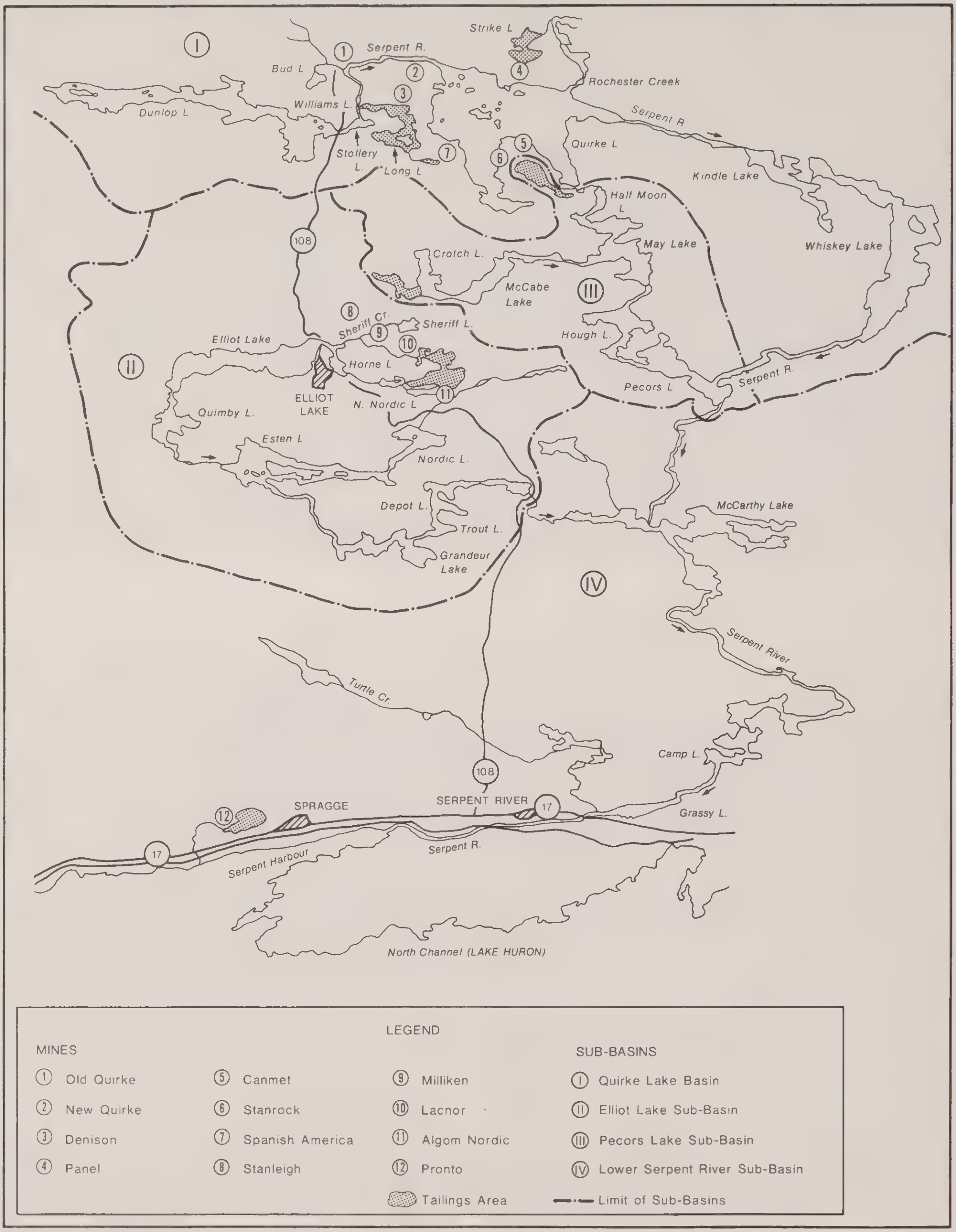


Water treatment pond, Cardinal River Coals Ltd., near Cadomin, Alberta
W.B. Blakeman, Environment Canada



Thickeners, Quirke Lake mine, Elliot Lake, Ontario
Jim Scott, Environment Canada

MAP 19. URANIUM MINING, SERPENT RIVER BASIN, ONTARIO



Source: Roy and Keller, 1976.

equally long-term and widespread environmental effects on water quality as illustrated in the following case study.

Case Study: Uranium Mining, Serpent River Basin, Ontario

Uranium mining in northern Ontario commenced in 1953 following the discovery of uranium-bearing ore in the Serpent River basin near Elliot Lake (*See Map 19*). Buoyant market conditions stimulated rapid development of the ore and, by 1953, eleven mines had commenced operations. A subsequent decline in market conditions reduced the number of operating mines to five by 1966 with a further reduction to two mines by 1972. Since 1972, many mines have been re-opened; in response to a renewed demand for nuclear fuels as a consequence of the 'energy crisis'.

The Ontario Water Resources Commission (now Ministry of the Environment) undertook surveillance of waste-control operations in 1957 with emphasis on the containment of tailings and the quality of receiving waters throughout the Serpent River basin. Studies to identify potential radioactive contamination were undertaken by the Ontario Department of Health commencing in 1958. The OWRC report, released in 1971, indicated serious chemical and radiological pollution throughout the basin. In certain lakes, radium 226 was present in amounts 50 to 200 times that of the normal background.

Serious pH depression was present together with significant concentrations of dissolved solids, sulphate, and ammonia. Severe impairment of biological conditions caused by degraded water quality was evident including reduced phytoplankton, zooplankton, and fish populations and depressed bottom-fauna communities. The report identified radiological contamination and its human health implications as the major concern followed by depressed pH and consequent reduction in the biological productivity of aquatic communities. Notwithstanding localized improvements in waste disposal practices between 1960 and 1970, Radium 226 activity remained at levels significantly in excess of background. Concentrations of dissolved solids showed gradual reductions between 1966 and 1970, but pH values continued to decrease even in lakes downstream of the neutralization sites.

Monitoring continued between 1970 and 1975, but despite the decrease in overall mining activity, water pollution continues to be a serious problem. While Radium 226 activity in general decreased significantly, levels at the mouth of the Serpent River continued to be slightly in excess of the concentrations considered permissible in domestic water supplies of 3 pCi/l. Throughout the basin, radioactivity levels in 1975 were variable, ranging from a low of 1 pCi/l at Elliot Lake to a high of 20pCi/l at the inlet to Pecors Lake. Overall, Radium 226 levels continued to be above acceptable standards due, in part, to contaminated drainage from abandoned tailings, spillages, and retention of radionuclides in lakes of the sub-basin.

Only relatively minor changes in pH values were recorded between 1970 and 1975. At the mouth of the Serpent River where pH value was considered to be representative of conditions in the watershed, the mean pH was 6.5, barely meeting the guidelines for the protection of fish and other aquatic life. The continuing declines throughout the basin were evidence of a serious ongoing problem caused, possibly, by the oxidation of large quantities of sulphides in the tailings, contributions from waste rock dumps, and/or relatively long residence of hydrogen ions in water. Further, ammonia, toxic to aquatic life depending upon temperature and pH, was in high concentrations and above the 0.2 milligrams/l found in unpolluted rivers. However, potentially toxic concentrations of ammonia were recorded only in the portion of the Quirke Lake sub-basin downstream from two active mills where pH was high.

The ongoing monitoring program reveals the significant spatial effects of mining residuals dispersion to surface waters; in the case of the Serpent River basin, a distance of some 93 killometres from the sampling station on the Serpent River at Hwy. 17 to the outlet of Depot Lake. The measurements obtained during the monitoring program are also indicative of the temporal effects of water pollution. Notwithstanding a reduction in mining activity, little progress appears to have been made in the ten-year period, 1966 to 1975, towards restoration of the water quality to acceptable standards. Mill-tailings effluents and residual radionuclides continue to pollute the waters in the basin and disallow operations of the naturally occurring restorative processes. On the basis of the record, it appears unlikely that water clarification will be achieved within the foreseeable future.

Source: Roy and Keller, 1976.

The potential for water pollution, however, is not confined to the extractive phases of mining. Both beneficiation and further processing stages provide opportunities, in greater or lesser degree, for the release of effluents into the aquatic environment.

Water Pollution from the Beneficiation Phase

The extensive use of water recycling in recent years has significantly reduced the potential for water pollution arising from the beneficiation processes. Nevertheless, most water is eventually discharged to impoundment areas, or settling ponds, where natural processes operate (seepage, evaporation, percolation, and runoff) and may allow the escape of toxic effluents to the surrounding environment. The effectiveness of the settling pond is partly a function of the time that the effluent can be contained. This may be as little as a few hours to several months depending upon the capacity of the impoundment (Down and Stocks, 1977). At this stage, measures are taken to neutralize the acidic elements in the water with alkaline materials, lime neutralization being the most widely employed process. Neutralization, however, must be sufficiently effective to ensure that the acid-forming capacity of the effluent materials is removed. Failure to apply sufficient neutralizer may result in re-acidification at downstream points remote from the original point of discharge (Whitt, 1970). An illustration of downstream re-acidification of tailings effluent is shown in Table 46. After neutralization and settling out of the effluent materials, substantial quantities of precipitated sludge remain which may present difficulties for dewatering and safe disposal.

The major environmental problem associated with the beneficiation stage is that of the disposal of mill tail-

TABLE 46. DOWNSTREAM ACIDIFICATION OF TAILINGS EFFLUENT

Parameter (mg/litre)	Kilometres downstream of discharge with initial pH of 5.6					
	0.3	1.85	3.23	7.48	8.93	21.06
pH value	3.5	5.0	5.6	2.6	2.5	3.0
SO_4	1,754	1,235	1,230	1,515	1,498	1,245
Copper	0.010	0.036	0.01	0.01	0.005	0.01
Zinc	0.38	2.0	1.8	2.5	1.4	1.8
Lead	1.0	1.1	3.0	1.2	0.65	0.7
Iron total	1.5	7.8	16.6	32.9	27.5	32.5
Ferrous	0.1	6.0	3.7	22.0	1.7	6.0
Ferric	1.4	1.8	12.9	10.9	25.8	26.5
Chemical oxygen demand	492	406	324	135	25.9	63.9

Source: Schimdt and Conn, 1969.

ings, the finely ground materials or gangue, resulting from the comminution and concentration phases (*see* Figure 9, Chapter 2). A variety of methods are used for the disposal of mill tailings. They include surface disposal, underwater disposal, underground disposal to backfill excavated areas within the mine, and further processing for secondary values (Mining Association of British Columbia, 1972; Ballantyne, 1975). Each of these methods has been used in Canada, although surface disposal continues to be the most common.

Despite the most-careful engineering studies, however, there is no guarantee that the waste-disposal methods will avoid contamination of the environment. A recent and on-going example of inadequate impoundment is the disposal of mill tailings from the Island Copper mining complex into the waters of Rupert Inlet, British Columbia. The following case study illustrates the consequences of a naturally occurring, and entirely unanticipated, effect.

Case study: Island Copper Mine, Vancouver Island

Since 1971, the Island Copper mining complex, located on the north shore of Rupert Inlet in British Columbia (*see* Map 20), has been producing copper-molybdenum at a rate of 33,000 tons per day from open-pit operations.

To satisfy government regulatory agencies, the corporation was required to develop an environmentally acceptable mill-tailings and waste-rock disposal system. Pre-operational studies indicated that the characteristics of the ore precluded storage of the mill tailings on land as they could be subject to bacteriological leaching into the surface waters of the adjacent watershed and pose a serious hazard to local salmon stocks and other resident biota. As an alternative, a marine-tailings disposal system was proposed on the basis of predictions that the tailings solids discharged directly into Rupert Inlet would remain below 100 metres and flow down the inlet's sloping bed to settle on the bottom. Further, the tailings would not be subject to spreading as the high current velocities would remain above the 60-metre level.

The marine disposal concept was accepted by the British Columbia Pollution Control Branch in 1971 and a permit was issued subject to the provision that an environmental monitoring program would be undertaken by an independent agency.

The surveillance and monitoring program conducted during the intervening years has revealed that the waste discharge has obliterated organisms at the lowest levels as anticipated in the original studies. There has been, however, another and entirely unanticipated effect. Widespread deposition of the tailings has occurred in the shallower, more biologically productive, areas of the system caused, it is believed, by tidal currents along the floor of Rupert Inlet. Contrary to expectation, high concentrations of suspended sediments have been observed at all depths accompanied by substantial increases in surface and subsurface turbidity. The dispersion of the solid effluents has far exceeded the original predictions to cause . . .heavy sediment deposition on much of the original substrate and resident biota in some intertidal and shallow subtidal areas.

The continuing deposition of wastes along the shallower sections of the shoreline is continuing to adversely impact resident biota by altering native habitat and smothering species. Simultaneously, deep-water benthos is being obliterated by the sediments on a much wider scale. It is anticipated that the biological productivity of Rupert Inlet will eventually be impaired by the subsequent reduction of species diversity and abundance.

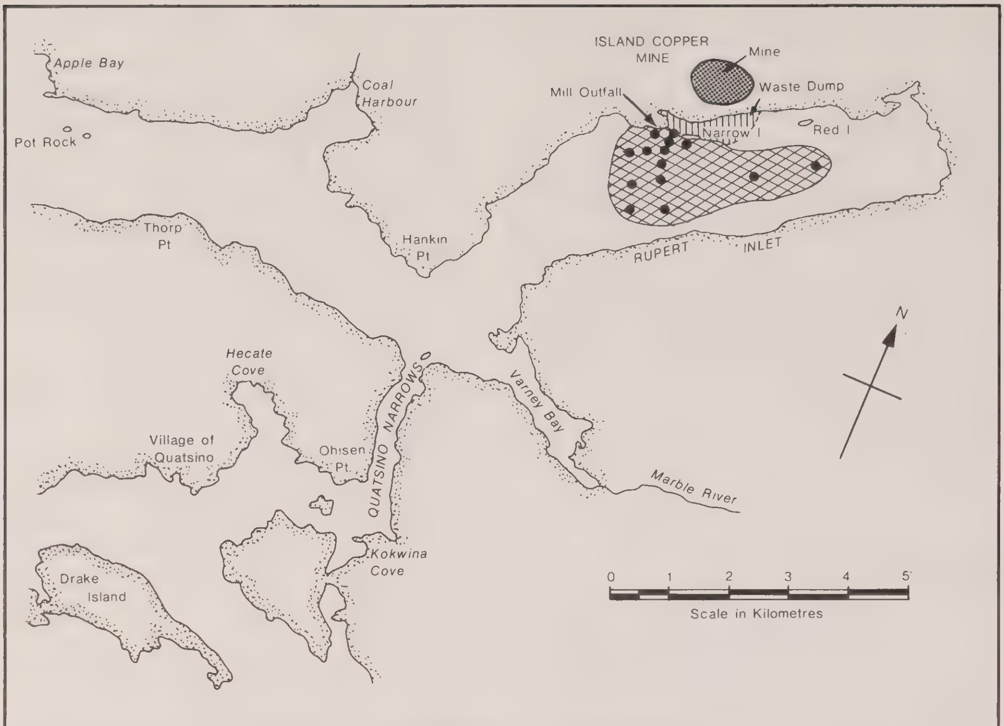
There also remains the potential for effects on human health as a consequence of the bioaccumulation of heavy metals in the tissue of bivalves. Molluscan filter feeders are able to concentrate toxic metals to levels far in excess of those found in their immediate environment. Increases in levels of copper have already been found in the tissues of local mussels; residuals of arsenic, lead, and cadmium are all present in the tailings effluent and could, in the future, be similarly absorbed.

The most recent surveillance report indicates that, on the basis of the current levels of environmental impact and the unpredicted spread of sediments into shallower water, the present tailings system should be re-evaluated. It suggests that changes in the design or location of the present underwater outfall system is unlikely to reduce or eliminate the widespread tailings dispersion.

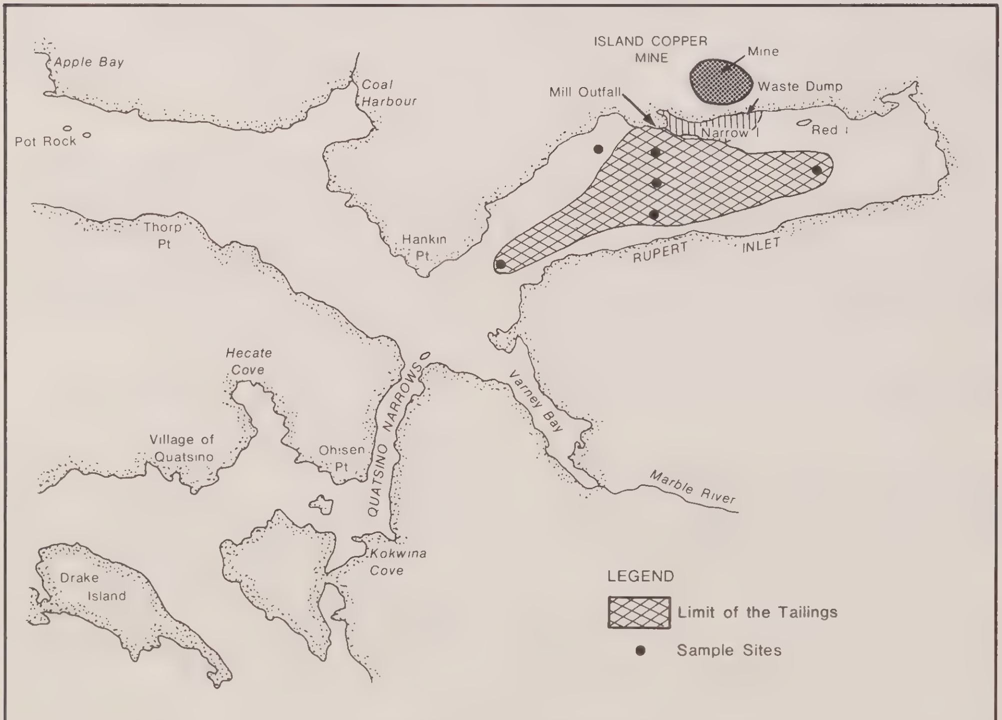
Source: Goyette and Nelson, 1977.

Above-ground disposal as tailings piles is a short-term and unsatisfactory substitute for an adequate impoundment area. The presence of slimes and water ensure the waste material's instability and vulnerability to water erosion. The common practice is to provide an impoundment area designed to accommodate the substantial quantities of waste materials generated. Effluent materials together with the water used in the mill beneficiation processes are conveyed to the

MAP 20. TAILINGS DISTRIBUTION, ISLAND COPPER MINE, RUPERT INLET, BRITISH COLUMBIA

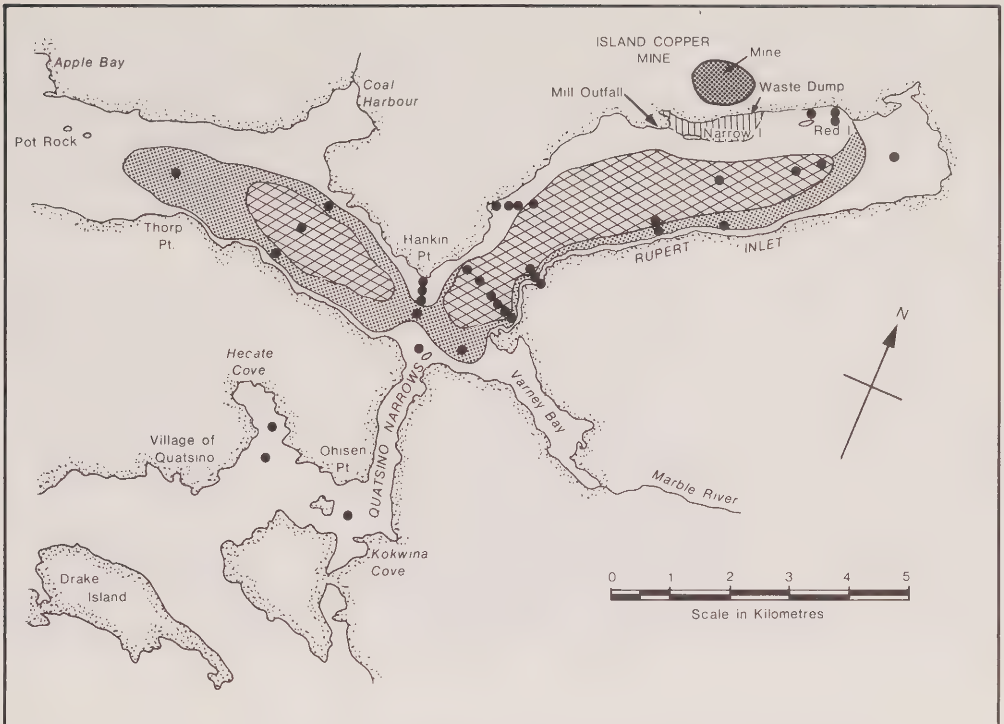


TAILINGS DISTRIBUTION NOVEMBER 3, 1971

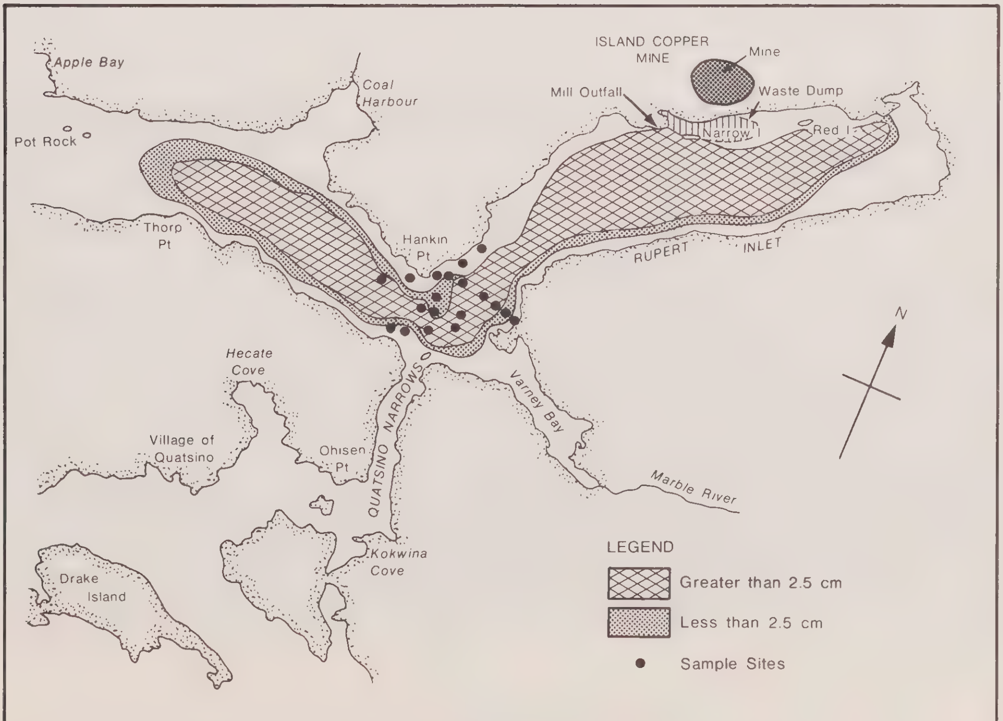


TAILINGS DISTRIBUTION MARCH 7, 1972

Source: Goyette and Nelson, 1977.



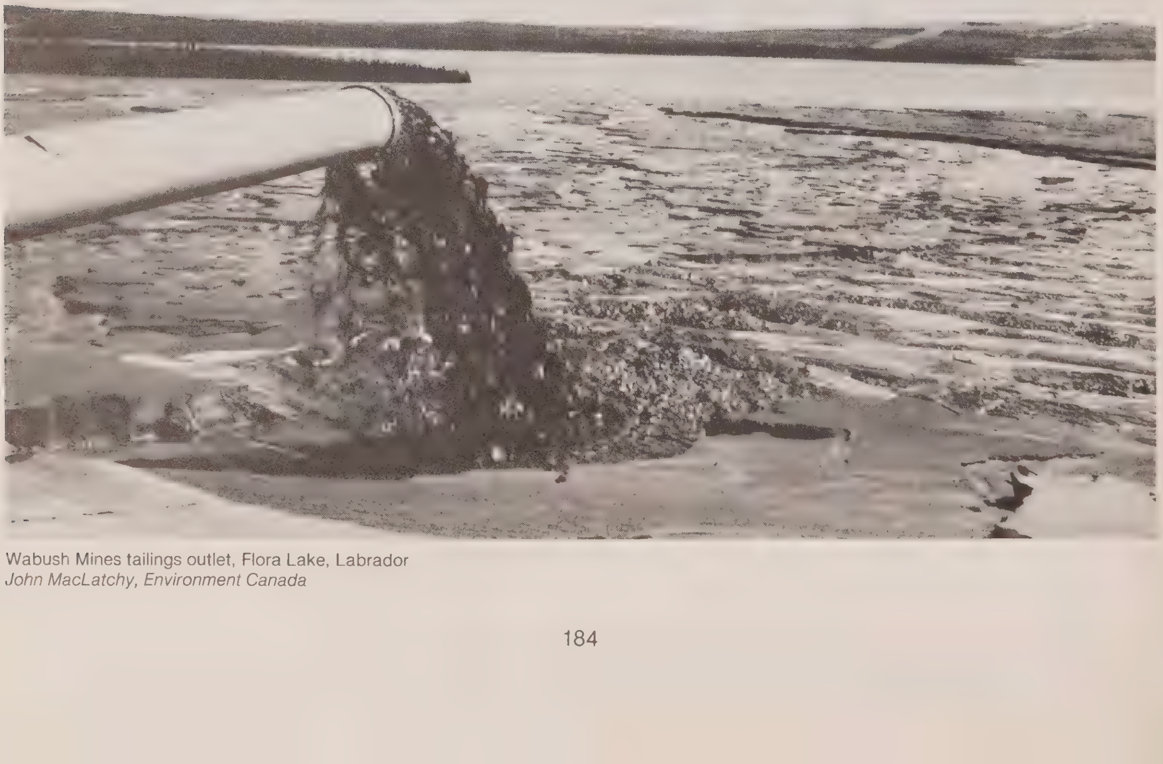
TAILINGS DISTRIBUTION OCTOBER 6, 1973



TAILINGS DISTRIBUTION MAY—JUNE 1974

Source: Goyette and Nelson, 1977.

Break in tailings dam.
Jim Scott, Environment Canada



Wabush Mines tailings outlet, Flora Lake, Labrador
John MacLatchy, Environment Canada

impoundment area as a slurry. Frequently, mine water is also discharged into the same impoundment. Invariably, the slurry contains quantities of organic reagents used in the mineral processing in addition to the constituents of the original ore. The reagents include frothers, collectors, depressants, pH modifiers, activating agents, flocculants, coagulants, and dispersants.

Many reagents are highly toxic and are known to be lethal to at least some organisms (Hawley, 1972; Leduc *et al.*, 1973). Table 47 shows the lethal concentration of selected milling reagents on a variety of aquatic organisms while Table 48 illustrates the concentrations of reagents at various stages during the processing and tailings impoundment circuit (*see* Chapter 2).

TABLE 47. TOXICITY OF SELECTED MILLING REAGENTS TO AQUATIC LIFE

Reagent	Lethal concentration (mg/litre)	Organism
Orthocresol	10	Perch, lower toxic limit, 15°C
	17	Perch, immobilized in 10 minutes 15°C.
Cresols	10	Crustacea killed in 2 hours.
Sodium Cyanide	0.05	Trout, 100% mortality, exposed 124 hours.
	0.8	Minnows, 100% mortality in 24 hours.
Cresylic Acid	3.12 - 6.60	Killed most chinook and silver salmon, exposed for 72 hours in both fresh and sea water.
Sodium Sulphide	1.0	Threshold, salmonoid fish
	1.8	Lethal, salmonoid fish.
Copper Sulphate	0.14	Trout
Sodium Cyanide	0.15 - 0.7	Minnows, 25% mortality, TL_m24.
	1.0	Trout, 100% mortality in 20 minutes.
Potassium Permanganate	4.0	Large mouth Bass
	5.2	Bluegill sunfish, TL_m24, Trout in 24 hours.

Source: Hawley, 1977.

TABLE 48. AVERAGE FLOTATION REAGENT CONCENTRATION AT VARIOUS STAGES OF A MILL/TAILINGS IMPOUNDMENT CIRCUIT

Reagent	Added to process on slurry basis	In-tailings slurry	In-water fraction of tailings
	(parts per million)		
Xanthate	13.0	1.8	1.2
Methyl isobutyl	8.0	-	2.0
Oils and greases	16.0	5.0	1.0
Sodium cyanide	12.5	0.9	0.2*

* With retention in tailings ponds this oxidizes to the less toxic cynate form.

Source: Mining Association of British Columbia, 1972.

The effectiveness of the impoundment in settling-out the particulate matter, dissipating chemicals, and degrading other toxic substances depends upon the period of time that the effluent remains in the pond(s). As in mine-water clarification, chemicals may be added to accelerate the dissipation processes. Nevertheless, once the water is impounded, some will be lost through natural processes and will eventually contaminate the environment. The quantity of water lost is a function of many variables including, among others, effectiveness of the design and construction of the tailings impoundment, climatic factors, soil properties, topography, proximity to watercourses, etc.

The design and construction of the impoundment area is critical to the maintenance of environmental quality. Embankment design and construction, transportation of waste materials, water retaining and decant systems, and seepage control are major design factors to be considered if the effects of earthflows, leaching, and wind and water erosion are to be minimized. Nevertheless, even the best engineering knowledge available may be insufficient, on occasions, to anticipate the occurrence of natural events, for example, the stressing of impoundment structures by sudden flooding. In March, 1975, two breaches in the tailings dykes at the Anvil Mine, Yukon, released almost 163 million gallons of tailings and decant (toxic and alkaline with a pH of 10.7) into the environment (Harvey, 1976). Spring run-off at the Pine Point mine, Northwest Territories has, in the past, caused as much as 50 percent of the effluent discharge to pass around the end of the tailings dyke thus circumventing the decant system (Stern and Miller, 1972). Accidents of this nature illustrate a clear need for improved predictive knowledge of the environmental processes involved in order to anticipate and avoid such events.

WATER POLLUTION FROM THE FURTHER PROCESSING PHASE

Whereas the beneficiation phase involves the mechanical and physical alteration of the ore, further processing, or extractive metallurgy, as the culminating phase, involves modification of the chemical nature of the minerals to isolate the metal from its sulphide or other compounds (*see* Chapter 2). These operations are not normally associated with the mining complex itself, but are located to serve a variety of differing mining operations within a larger regional area and to take advantage of adequate transportation facilities for distribution of the finished product.

In addition to the problems associated with the emission of atmospheric pollutants previously discussed,

the other major residual of the further processing stage is that of smelter and refinery slags. Compared to the production of mill tailings, the quantities of slag generated are approximately one-fifteenth of those of the tailings on the basis of weight (Ripley *et al.*, 1978). These slags typically contain one-third each of metallic oxides, silica, and iron oxides (Dennis, 1965). Unlike mill tailings, however, these slags are generally physically more stable and chemically inert. As the waste quantities involved are relatively small, it presents less opportunity for environmental damage.

Consequently, its disposal has not been a matter for great concern. Nevertheless, while there are few direct emissions to the hydrosphere from the further processing stage, smelter waste water has been shown to affect water quality when dumped directly into an aquatic environment (Reeder, 1971). While smelter slags discharged into the Columbia River had little effect on water quality, the accompanying smelter water increased the hardness of the river water and its content of sulphate, calcium, fluoride, phosphate, and zinc. Full dilution of the effluent only occurred 5 to 15 kilometres downstream from the point of discharge.

TABLE 49. ENVIRONMENTAL EFFECTS OF THE VARIOUS METALLURGICAL METHODS USED

Metallurgical Methods	Environmental Advantages	Environmental Disadvantages
Pyrometallurgy	Minimal liquid wastes, lower energy requirements.	Less-pleasant working environment. Fine grinding necessary, large energy sink. Chemical reagents required for flotation process. Sulphur dioxide emissions.
Hydrometallurgy	Little discharge to the environment if performed on closed-circuit basis. Tailings generally less finely ground than for pyrometallurgy. Greater potential for integration with ancillary operations.	Waste solutions may be released to environment. Less energy requirement.
Electrometallurgy	Produces high-purity products. High degree of control possible.	Large amount of electrical energy required. Production of electroly mists and some toxic gases. Possible toxic chemical wastes to hydrosphere. Generally has to be used together with one of pyrometallurgy or hydrometallurgy.

Source: Ripley et al., 1978.

Diversion channel for fish, Cypress Anvil Corp. Ltd. mine, Faro, Yukon
W.B. Blakeman, Environment Canada

In Table 49 the environmental effects of the various metallurgical methods used during the further processing stage are listed. Considerable variations exist within the stages depending upon the mineral characteristics of the ore mined. Nevertheless, the residuals released to both the atmosphere and hydrosphere are fairly typical.

SYNOPSIS OF IMPACTS

In the preceeding pages, the nature, extent, and possible effects of mining residuals have been examined in relation to their local, regional, and global effects upon land, air, and water. Table 50 summarizes the relationship between mining activities and their effects on land, water, and biological resources. It is evident that the potential environmental impacts attributable to the mining industry are many and varied, ranging from minor changes in vegetation cover, to severe and permanent land degradation. However, many of the potential effects identified can be reduced significantly if known remedial procedures are introduced. It is beyond the scope of this overview to attempt to review their total range in an exhaustive way, but an attempt has been made to convey, through the use of cases studies, some indication of the potential severity of those environmental problems which occur beyond the actual mine site and which seem to pose the greater environmental threat. Land degradation is one of the more frequently cited consequences of mining activity; its consequences are both visual and immediate. Invariably, mining operations located in close proximity to more densely populated regions may be expected to raise greater controversy over environmental issues than activities located in more-remote regions (for example, pits and quarries of the aggregate industry). Disturbed land, however, is only one facet of the environmental problems associated with mining. There are other, more-subtle effects which are neither visible nor immediate, and which extend far beyond the immediate site of mining operations. These have been referred to as the 'shadow effects'. Dust, run-off, seepage, traffic, fumes, vibration, and noise all contribute to the shadow effect of mineral production and to localized physical and chemical changes in the environment. Nevertheless, wider regional and even global impacts occur as a result of the beneficiation and further processing stages. Indeed, the 'shadow effect' may indeterminantly affect an area hundreds of times greater than the actual mine site. Under the circumstances it is not surprising that mining will invariably become involved in land use conflicts.

TABLE 50. RELATIONSHIP BETWEEN MAJOR MINING PHASES AND THE MECHANISMS OF IMPACT ON LAND AND BIOLOGICAL RESOURCES[1]

Impact Mechanisms	Local: Within the 'mine Site'[2]						Regional: 'Shadow Effect' beyond the mine site					
	Mining Activity						Mining Activity					
	Development	Extraction - Underground	Extraction - Surface	Beneficiation/Storage	Further Processing - Pyrometallurgical	Further Processing - Hydrometallurgical electrometallurgical	Development	Extraction - Underground	Extraction - Surface	Beneficiation/Storage	Further Processing - Pyrometallurgical	Further Processing - Hydrometallurgical electrometallurgical
Surface Disturbance												
Direct Removal of Soils - Subsoil	XX	X	XX	XX	XX	X	X		X			
Change in Soil Quality												
Physical	XX		X		X		X		X			
Chemical/Biological				X	XX	X				X	XX	
Vegetational Changes												
Direct Removal	XX		XX	X								
Modification of Species/ Density Changes	XX	X	XX	X	X	X			X	X	X	X
Wildlife Changes												
Loss of Habitat	XX	X	XX	X	X	X			X	X	X	X
Barrier to Movement	XX	X	XX	X	X	X	X					
Change in Water Quality												
Temperature					X	XX					X	
Chemical		XX	X	X	XX	XX		XX	X	XX	XX	XX
Particulates	X	X	X	XX	X	XX	X	X	X	XX	X	X
Changes in Water Movement												
Surface	XX	X	XX	XX	XX	XX	X		X		X	X
Underground	X	XX	XX		X	X			X			
Change in Air Quality												
Chemical					XX	X					XX	
Particulates	X	X	X	XX	X		X		X	X	X	
Microclimate					X						X	
NOISE/Ground Shock	XX		X	XX	X		X		X	X		

[blank] - unanticipated or insignificant. x - Slight xx - Moderate to major.

1 The table represents a generalization for the mining industry as a whole. Many of the potential impacts identified can be reduced significantly if known remedial procedures are introduced to reduce the potential impact on land and biological resources.

2 Includes the area within the mine site boundary and a local buffer zone of 1-2 km. Included here are the sites of smelters and refineries.

Revegetation test plots on abandoned mine tailings, Sudbury, Ontario
I.B. Marshall, Environment Canada

Chapter Six

LAND USE CONFLICTS AND CONSTRAINTS

The direct effects of most mining operations within the "mine site" while not negligible are localized and relatively small compared to many other forms of human economic activity such as agriculture, forestry, and urban settlement. That mining will have a considerable influence on the land surrounding its operations is inevitable, and this influence, referred to as the "shadow effect", is far more extensive than previously estimated. In addition, the indirect effects of mining can be quite large, especially the infrastructure developed for mining operations (rail, roads, housing power plants, water storage, and other facilities). It can significantly extend the land area directly influenced by all mine-related activities and often permits a large number of other activities that would be difficult or impossible to undertake without it.

Indeed the interplay of the direct uses at the "mine site" and other land uses in the "shadow" zone illustrate the areas of increased responsibility that have been assigned to mining operations. In the past decade, a mining company's responsibility for environmental protection has been dramatically projected beyond the visible perimeters of their working operations, to substantially larger neighbouring lands. In effect, changing environmental regulations have assigned an increasing degree of responsibility to the mining company to minimize the environmental impact of its operations on the use of neighbouring lands. It has resulted in a continued and increasing interaction, desired or not, with landowners and resource managers responsible for the land use activities bordering mine sites (Figure 22). The range of interaction between mining and other land uses has become increasingly complex. No longer is it a straight economic or technological choice between competitive uses. Demands for resource conservation, environmental protection, and restricted use, coupled with the wide range of traditional uses — agriculture, forestry, settlement, recreation — have all increased the potential constraints on development and the actual number of conflicts.

Over the last few decades there has been a growing indication that mining developments are being allocated lower social desirability than competing land uses. Much of this no doubt has been due to a past history of abandoned operations and their adverse effects on the local environment. Public attention to the allocation of land to certain uses has also been heightened by increased publicity about the scarcity of certain land resources, and threats to them from an increasing array of degradation processes, both real and perceived.

Although the public has been aware for some time of the effects of mining operations, the deterioration of the land resource base attributable to other land use activities, particularly those centred around the agriculture and forest industries are now believed to be equally extensive, if not greater. This has only served to heighten the pressure on new industrial developments (particularly those associated with mineral and energy resources) and clouds their acceptance as a legitimate option in the highly emotional process of land allocation.

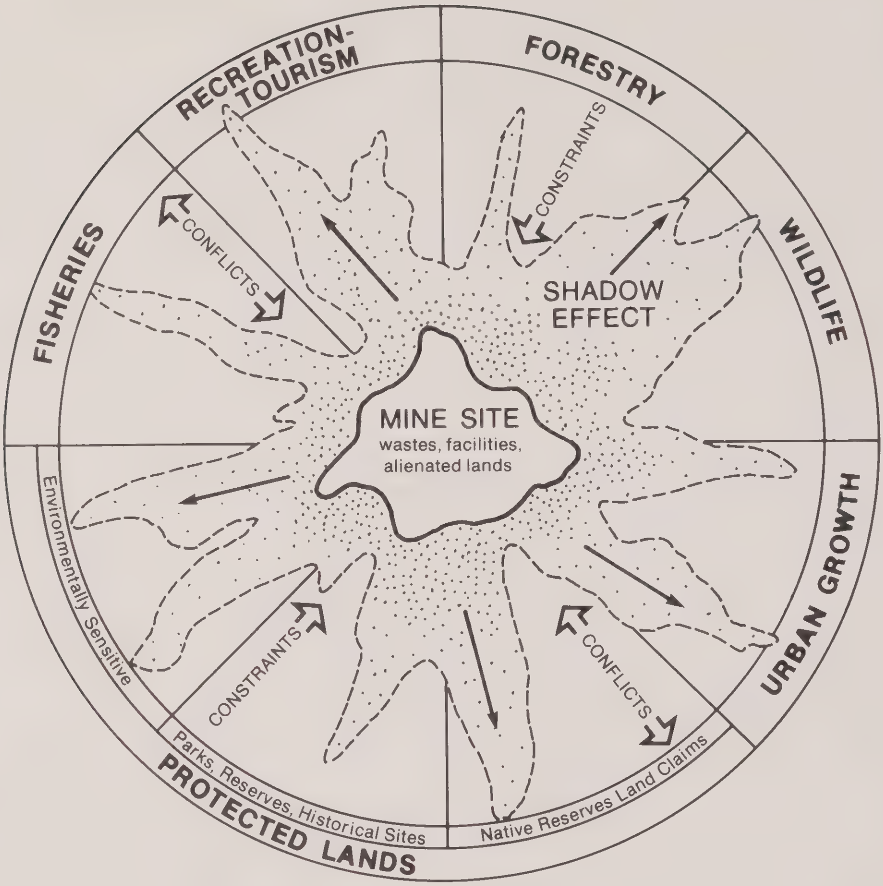
Mining options in Canada, as elsewhere, are limited to the presence of commercially developable mineral deposits. This is similar to other resource-dependent activities: National Parks are located where the natural features or phenomena occur; and hydro-electric developments are limited to those waterways where sufficient head, flow, and drop exist. Looked at in the same perspective, agriculture and forestry seem far more flexible in location, yet they too, have specific requirements, such as soil and temperature. Their high profile in our consumptive pattern become the focus of attention when competition for land occurs. It is imperative then that the Canadian society be aware of the interrelationships, needs, and problems arising from the various economic sectors of our society, including mining, in order that decisions on land allocation reflect the needs and concerns of all Canadians.

LAND RESOURCE IN PERSPECTIVE

Although Canada is the second largest country in the world, its vast size is deceptive. Much of the land is severely limited for productive use by adverse climate,

Mining industries, Sudbury Region, Ontario
NFB — Phototheque — ONF, Karl Sommerer

FIGURE 22. CONCEPTUAL LAND USE CONFLICTS AND CONSTRAINTS FOR MINING



topography, and soil conditions. The total area of Canada is 997,316,000 hectares of which 75,516,000 hectares consists of fresh water areas (Table 51). The land surface can be described as follows:

(i) More than half (55 percent) of Canada's land resources are "wildland": a combination of frozen arctic islands, associated barren lands, rock and muskeg in a climatic environment incapable of supporting any but limited growth in terms of forest or a tundra-forest vegetation, and that for only a short growing period each year.

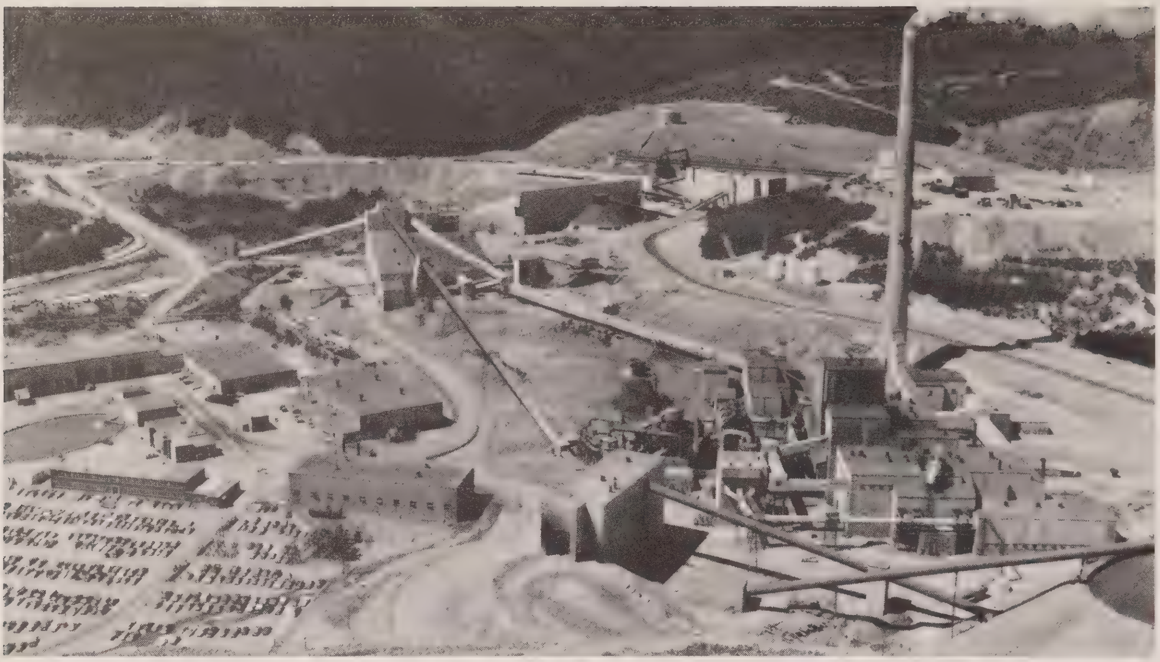
(ii) A further 37 percent of the land area is forest land climatically capable of sustaining vegetative growth, but approximately one-third of this area has climatic limitations that restrict the growth of forest species for productive commercial forestry.

(iii) Most of the rest of the land falls into the agriculture ecumene (eight percent) and a small amount (less than one percent) is occupied by urban settlements and their associated internal roads, parks, and greenbelts.

TABLE 51. LAND USE IN CANADA

LAND RESOURCE BASE	(000's hectares)	SPECIAL LAND USES	(000's hectares)
Agriculture areas	73,000	Transport	
		Railways	506
Forestry		Highways, roads, streets	2,590
Productive	207,900	Airports	613
Unproductive	94,800	Marine transport	44
Unclassified	39,000		
		Mining	
Wildland	503,700	Claims, grants, leases	39,600
		Land disturbed and alienated from alternate use	285
Urban			
Built up	1,569		
Roads, parks, greenbelts	1,831	Energy	
		Petroleum leases (on shore)	65,600
Fresh water areas	75,516	Petroleum pipelines	60
		Natural gas pipelines	80
		Electrical transmission lines	340
		Hydro-electric headpond storage	1,620
		Protected lands	
		Parks and park reserves	39,590
		Wildlife protection areas	56,879
		Indian reserves	2,927
		Military bases and reserves	
		Owned	597
		Leased	1,206
CANADA Total	997,316		

Sources: Swan, 1978; Simpson-Lewis, 1979; Hamilton, 1980 and Welch, 1980.



Concentrator and mill. Gaspé Mines, Murdochville, Quebec
NFB — Phoptotheque — ONF, George Hunter

Land use has remained fairly constant in the past decade. Less than three percent of the total land in Canada is directly used for energy and mineral production, commerce and industry, transportation, water storage, and other consumptive land uses (*see* Table 51). However, this figure does not reflect its true effect on the surrounding lands. Protected lands (parks, park reserves, wildlife protection areas, Indian reserves, and military bases and reserves) within the wildland, forest, and agriculture ecumenes account for approximately 11 percent of the land area.

In the United States, by contrast, nearly 80 percent of the land is used for agriculture and forestry. About one-fifth is cropland, one-quarter is pasture or range, and one-third is forest land. This is almost double the area available to Canada for renewable resource uses and, more significantly, it is under far less-severe limitations. The myth that Canada, as the world's second largest nation, knows no limit to its economic resource potential quickly dissipates with the realization that our resources are considerably more finite, and in some cases, scarce.

Further, a number of trends have emerged over the past two decades which put increased pressure on the availability of some lands for future development, namely: an increase in protected or limited-use lands; deterioration in the physical quality of the land; and the changing perception and attitudes of society towards the conservation and protection of the environment. These trends are discussed in the following sections in the light of their cumulative effect on the future of mining development in Canada.

LAND USE PRACTICE AND THE DETERIORATING QUALITY OF LAND

Many of the processes in the mining industry that lead to a deterioration in land quality — physical alteration, chemical degradation, and biological, aesthetic, and cultural disruption — are evident to varying degrees in all areas of human activity. Those processes can be separated into two broad groups, local and regional. Land degradation, in its broadest sense includes not only man-induced, but also natural, processes. Many of the natural processes involved in land degradation, for example, flooding, and wind and water erosion, are accelerated by exploitation and poor management, or a lack of proper land use planning.

The main objective of this section is to identify the emerging trends related to the deterioration in the quality of land attributable to past management and land use practices. Identification of these problems is not exhaustive but serves to provide an indication of

the extent to which land misuse exists beyond the mining industry. It draws attention to the fact that land degradation has many faces and is a much-wider problem than previously perceived.

This deterioration in the quality of land dedicated to traditional land uses (e.g. forestry, agricultural, tourism, and recreation) increases the desire to protect and resist more direct and visible forms of disturbance particularly energy or mineral-related developments which are associated with the permanent alteration of the land.

AGRICULTURE

The Canada Land Inventory (CLI) evaluation of the physical land-resource base reveals that a very limited portion can be classified as prime agricultural land (Simpson-Lewis *et al.*, 1979).

(i) Less than 14 percent of Canada's land area has some potential for agricultural use (classes 1 to 6).

(ii) Only 45,993,529 hectares or 5 percent of Canada's land area is free from severe physical limitations to crop production (classes 1 to 3).

(iii) Approximately 6.5 percent or 59,192,983 hectares have severe to very severe limitations to crop production (classes 4 and 5).

This leaves approximately two percent or 18,363,430 hectares suitable only for rough grazing (class 6).

Most of the undeveloped land capable of agriculture production is presently under forest cover (usually classes 3 to 5 in quality). In 1976, only 67,168,202 hectares of land were being farmed, 35 percent of which remained unimproved (Statistics Canada, 1977).

In the past decade, there has been a growing concern about the agricultural land-resource base, particularly the conversion of land in general and the decreasing quality of the remaining agricultural lands.[21] The nature of land use issue with particular regard to agriculture trends was described as follows:

"Land uses, as well as the factors which determine land use patterns, represent extremely complex subject areas involving perceptions, historical development, socio-economics, geography, and peoples expectations all within a political decision-making context. As in any other areas involving such varied interests, there is some lack of agreement concerning the seriousness of agriculturally-related land use issues and the trends evident over the last few decades. Nevertheless, the abandonment of marginal farmland, fluctuating prices at the farm gate or retail level, shifting of land uses from less intensive to more intensive, declining soil quality, rising production costs, the cost/price squeeze, demographic changes, selling of prime farmland for urban or recreational purposes, eroding of unique soil resource areas, or climatic changes and their possible ramifications, all relate back to the land base for agriculture." (Simpson-Lewis et al., 1979).

The decreasing agricultural land base has been well documented (Gierman, 1977) and can be largely attributed to the abandonment of marginal farmland and the loss of prime agricultural land to urban and recreational purposes (Gierman, 1977; Manning and McCuaig, 1977; Neimanis, 1979).

More significant are the serious changes in the physical quality of agricultural lands. The increased use of monocultural practices in Canada has led to the loss of organic matter (as much as 40 to 50 percent), reduced the overall stability of soils and resulted in greater redistribution of surface water and hence increased rates of soil erosion (Ketcheson *et al.*, 1979; Rennie, 1979; Siemens, 1979). The erosion and transport of soil particles from agricultural lands in the Great Lakes basin is also responsible for the bulk of phosphorus pollution from farmland. Agriculture contributed 25 percent of the total phosphorus load to the Great Lakes and about 60 percent of the total diffuse tributary load (Coote, 1980).

Changes in soil quality in the Prairie region of western Canada are more profound than any other part of Canada (Rennie, 1978; Vander Pluym, 1978). The major causes of deterioration have been identified as loss of organic matter, declining soil nitrogen, and increasing soil salinity. Rennie (1978, 1979) has identified excessive cultivation every second year as the heart of the problem. An average of 47 percent of the farmland in Saskatchewan was in summer fallow (almost 40 percent for all of Canada in relation to land under crops). Summer fallow, originally conceived for the dust bowl conditions of the 1930's, has ceased to be related to its original purpose of conserving water. It is now used as a means of regenerating fertility, controlling weeds or, in periods of poor grain sales, to limit production. The most visible of these problems in the

[21] A number of these concerns have been documented in the following publications: Williams, 1973; AIC, 1975; Pearson, 1975; Gierman, 1977; Kreuger 1976 and 1978; Bentley, 1978; Rennie and Ellis, 1978; AIC, 1979; Neimanis, 1979. For a complete coverage *see* Simpson-Lewis *et al.*, 1979; and Coote, *et al.*, 1981 (*in press*).

Great Plains is excessive dry-land saline seepage, a direct result of a monoculture wheat-fallow rotation (Vander Pluym, 1978). In Saskatchewan, current estimates are that two million hectares of cultivated land are affected, with 400,000 hectares severely affected (Johnson, 1979). In Alberta, about 50,000 hectares (22 percent) of the irrigated land is believed to be affected by some form of salinity (Vander Pluym, 1978). In fact, Rennie (1978) attributes all these problems to the fact that farmers have been "mining the soil", that is, taking more nutrients out than they are replacing.

The concerns about Canada's agricultural land resource were summarized in the opening address to the 1978 International Soil Science Congress in Edmonton:

"..., the loss to agriculture of prime quality land is most extensive and most serious in the very best agricultural land areas of Canada —— southern Ontario and the St. Lawrence Lowlands.

"Axiomatically loss of prime agricultural land, and its replacement for food production by areas of lower land quality, will tend to increase costs of production. Food costs will tend to rise at home and potential purchasers of Canadian agricultural exports will be less able to purchase our high-priced products.

"Public attitudes to land resource inventories and evaluations by scientists may be likened to some contemporary attitudes about energy. Either the general citizenry refuse to believe the competent specialists or they disregard efforts being made to inform them of the rapidly deteriorating resource position. Surely future generations will find inexcusable our profligate squandering and abuse of the agricultural land resources during the second half of the twentieth century." (Bentley, 1978).

FORESTRY

Forest lands total 3.4 million square kilometres of which only two million square kilometres are commercially productive and much of this apparent reserve cannot be used for conventional forest products because of remoteness, small or defective trees, and species of little current commercial value (Environment Canada, 1979*d*). Serious problems facing the industry include losses through fire, disease, insects, and poor management which have reduced the available commercial stocks substantially. Total losses attributed to insects, diseases, and fire are believed to be nearly equal in volume (140 million cubic metres) to the annual commercial harvest of wood (Environment Canada, 1979*d*). Fires destroy an average of 809,400 hectares of forest per year. It is estimated that 75 percent of these fires are started by humans, but lightning-caused forest fires account for half the area burned (Simpson-Lewis *et al.*, 1979).

Poor management is by far the most-serious factor affecting the vitality of Canada's forests.

"Unless forest management becomes more intensive, there is a serious question whether present timber harvests can be maintained or expanded in the future even if rising prices for wood make more of the existing inventory economically available. The principal reasons for this are: (1) Withdrawals of forest land for parks, wilderness areas, roads and other non-timber uses are reducing the forest land base available for timber production. (2) The unbalanced age-class distribution of Canada's forests will lead to a period when fewer forests will be reaching maturity and the volume of harvestable wood will tend to decline even if logged-over areas are regenerated promptly. (3) Much forest land supports brush or poor quality hardwood stands owing to lack of prompt reforestation following logging or fire. (4) The yield of second growth forest stands may be less than those of the original stands owing to lower stocking, poorer species composition and shorter rotations unless intensive forest management is undertaken. To reiterate, more intensive forest management is essential to maintain Canada's future wood supply." (Environment Canada, 1979d).

The area of productive forest not adequately restocked covers 12 percent of the total and is increasing by 193,000 hectares a year (Morgenstern, 1978). The back-log will have more than doubled in 14 years, unless something is done. Much of the problem is reportedly the lack of money and manpower. It is of concern that the vitality of the forest-resource sector cannot help but have a significant influence on other uses of the forests, on a local or regional basis, particularly those associated with recreation, tourism, and wildlife habitat.

Many other activities are seriously disrupting forest lands. For example, in Alberta, the oil exploration and extraction industry has a more-negative impact on the forest zone than any other operation. The major concerns about forested areas affected by mineral exploration and other industrial users are that:

(i) Increased access causes harassment of wildlife on feeding and breeding grounds, allows overhunting, overfishing, and uncontrolled use by all-terrain vehicles, and lowers recreation values.
(ii) Erosion and stream siltation increase.
(iii) Prime commercial timber production land is lost for at least one rotation (80 years) even with prompt regeneration, which reduces the overall allowable cut. It raises the problem of proper forest management when it is constantly being disturbed by exploration operations.

The problem of choosing what resources will be developed in a land area and whether it will be a single dominant use or multiple use is becoming more and more critical. Although less than two-thirds of forest land is considered commercially productive, the importance of total forest ecumene to other non-commercial activities is vital. The forests provide the vital background to much of the outdoor recreation industry and provide habitat for fish and wildlife, including spawning and breeding habitats for continental and/or internally significant fish and wildlife populations.

OUTDOOR RECREATION AND TOURISM

Nowhere is this dilemma of single or multiple use of Canada's forest lands more prevalent than in those areas where the attractiveness of the landscape forms the basis for outdoor recreation and tourism. In the past two decades, the combination of increased leisure time and more disposable income has led to a more-mobile urban population demanding facilities for outdoor recreation. This demand can take many forms ranging from scenic driving for pleasure, swimming, boating, camping, hiking, hunting and fishing to specialized activities such as white-water canoeing, skiing, and mountain climbing. Common to all is the need for the use of the land. Much of the demand is reflected in the use of forested crown lands, some private lands and especially those protected lands such as parks, park reserves, wildlife reserves, and wilderness areas.

Much of the potential high-quality recreation lands coincides with more-accessible commercial forest and fisheries areas found in the uplands, hills, or mountains of the Canadian Shield, Cordillera, and Appalachian regions bordering the agriculturally dominated plains or highland valleys. In this forest ecumene is located a multi-billion dollar outdoor recreation and tourism industry. The importance of proper forest management to this industry is reflected in the following comments on forest disturbance in Alberta.

"Reclamation of disturbed forest lands to an adequate standard is essential. Not only must gradual depletion of the forest land base be prevented, but watershed condition, capability to produce timber and forage, habitats for fish and wildlife and the aesthetics of the land for recreation must be protected or replaced as the case may be. Recreational uses of forest lands by the public, especially on the eastern slopes of the Rockies, is increasing rapidly and taking place over larger and larger areas of land. Maintaining recreational values, then, is one of the principal objectives of reclamation." (Smart, 1977).

This example is not exclusive to the situation in Alberta but reflects a growing concern across Canada wherever outdoor recreation plays a significant factor in local and regional economics. Much of the pressure for access to open space is placed on land within a 160- to 240-kilometre radius of population centres, particularly shorelines for boating, lodging and boat launching (Taylor, 1978). Other activities require a more-varied landscape which provide a scenic view, fish and wildlife habitats, climbing, or skiing.

An important aspect of the demand for land resources devoted to recreational use, will be the need to obtain a more-visible economic return for tying up the land to a single use. In most cases, the focus will be to increase tourism, emphasizing the same attractions. Like outdoor recreation, to attract tourists a clean environment is required. Tourists can help to provide a monetary value to protected lands — wildlife reserves, parks, monuments — but too many can also endanger the very reason for which the lands were set aside. The combination of internal Canadian demands for lands devoted to recreation use, coupled with their attraction to tourists can have a significant influence on the allocation of land resources.

The increased rate of outdoor activity also has adverse effects on the quality of forest land, and some of the problems have been outlined by the Environment Council of Alberta (1979). Many problems followed the increased exploration and development of non-renewable resources (oil, gas, and coal). Increased access to remote lands has led to overhunting, overfishing, and harassment of wildlife. Use of seismic lines has slowed down revegetation, and the use of access roads in wet weather has aggravated erosion and stream sedimentation. However, the responsibility for reclaiming and cleaning up damage lies with the resource company

responsible for their placement, but the re-use of seismic lines and access roads for other activities make it difficult to apportion responsibility.

The land-resource base will continue to be altered in order to meet society's demands for food production, housing, forest products, transport and other related services. It is unlikely that we shall ever see less disturbance to the environment than is present today, due to the continued growth and the demands which will follow to meet their needs. Under such continued pressure, the carrying capacity of the land resource is threatened and it will become increasingly necessary to institute environmental and conservation measures to ensure its continued viability. Under these circumstances public accommodation of the more highly visible and disruptive developments such as mining, become more and more difficult to achieve. Mining is not viewed as part of a general lifestyle (excluding mining-dependent towns); as an essential daily service; as involved in vital food or fibre production; or as part of an essential transport and communication network. Mining causes far more public outcry and public demands for environmental protection and reclamation, or outright exclusion from the use of certain lands. This despite the fact that there are very serious problems of degradation associated with traditional approaches to food and fibre production and to services industries.

PROTECTED OR LIMITED-USE LANDS

Of the many problems facing a new mine development, or any major development for that matter, is the likelihood that the land in question may have already been placed under some category of official or non-official protection. Protected areas usually fall into the

TABLE 52. NATIONAL AND PROVINCIAL PARKS AND RESERVES ESSENTIAL FOR WILDLIFE HABITAT*, By Province and Territory, 1976

PROVINCE/TERRITORY	NATIONAL PARKS	PROVINCIAL PARKS	PARK RESERVES	TOTAL
	(hectares)			
Newfoundland	233,907	739,191	34,067	1,007,165
Prince Edward Island	1,813	1,275	1,345	4,433
Nova Scotia	133,206	1,888	6,597	141,691
New Brunswick	43,124	21,526	-	64,650
Quebec	114,040+	8,898,460	4,054,656	3,067,156
Ontario	191,171	3,962,274	511,684	14,665,129
Manitoba	297,596	878,178	3,558	1,179,332
Saskatchewan	387,470	511,882	4,988	904,340
Alberta	5,301,044	651,386	80,200	6,032,630
British Columbia	444,296	4,539,874	-	4,984,170
Yukon Territory	2,201,538	-	979,558	3,181,096
Northwest Territories	3,607,932	2,209	747,603++	4,357,744
CANADA	12,957,137	20,208,143	6,424,256	39,589,536

* Parks essential for wildlife area derived from the Parks Classification System and include:
Class A - Wilderness Areas (minimum size of 11,620 ha)
Class C - Unique Natural Areas or Monuments
Class D - Natural Environment Recreation Areas (minimum size of 202 ha)
Class G - Park and Recreational Reserves (Land Bank)

\+ Includes Gatineau Park, 35,613 ha; controlled by National Capital Commission.
++ Includes East Arm, Great Slave Lake, N.W.T., 740,753 ha.

Source: Simpson-Lewis *et al.*, 1979.

category of sensitive lands or lands of unique and representative environments of regional or national importance. Uniqueness of land is referred to here in the sense that they cannot be disturbed without some negative result and cost. Lands which are not to be disturbed have been generally defined:

..."as those land and/or water areas which because of some biophysical, historical or cultural characteristics, are determined to be unique, highly productive, rare, fragile, perishable, or, as they function in their natural state, hazardous to human health, safety and welfare." (Mertes, 1978).

The categories of protected lands differ nationally in their objectives, scope, and method of implementation, in their statutory authority and assumed permanence, particularly to the extent to which there may be overlapping jurisdiction. In Canada, the main categories are parks, reserves, wildlife protected lands, historic and archeological sites, IBP sites, and Indian reserves. In some cases these protected lands are by no means mutually exclusive; for example, parks may be wildlife preserves as well.

PARKS, RESERVES, AND DESIGNATED SITES

In Canada, there are 39,589,536 hectares (four percent of total land area) of land devoted to national and provincial park, and park reserves Table 52 and Map 21). National Park objectives are designed:

"To protect for all time representative natural areas of Canadian significance in a system of national parks, and to encourage public understanding, appreciation and enjoyment of this natural heritage so as to leave it unimpaired for future generations."

and in the case of National Historic Parks:

"To protect for all time historic resources at places associated with persons, places and events of national historic significance in a system of national historic parks, and to encourage public understanding, appreciation and enjoyment of this historical heritage so as to leave it unimpaired for future generations." (Parks Canada, 1979).

The principle objective of provincial parks is to reserve land for recreation, with some sites being preserved for scientific purposes. The uses permitted within the parks vary considerably within and among the provinces (Carlisle and Maini, 1974). For example, Alberta has several classes of parks (wilderness, historical, ethnological, archeological, natural environment, recreation, parkways, and commission), but divides them into three types of uses; scientific study and recreation, mainly recreational, and multi-purpose. No commercial logging is permitted in National Parks, but it is allowed in some provincial parks provided it follows prescribed guidelines.

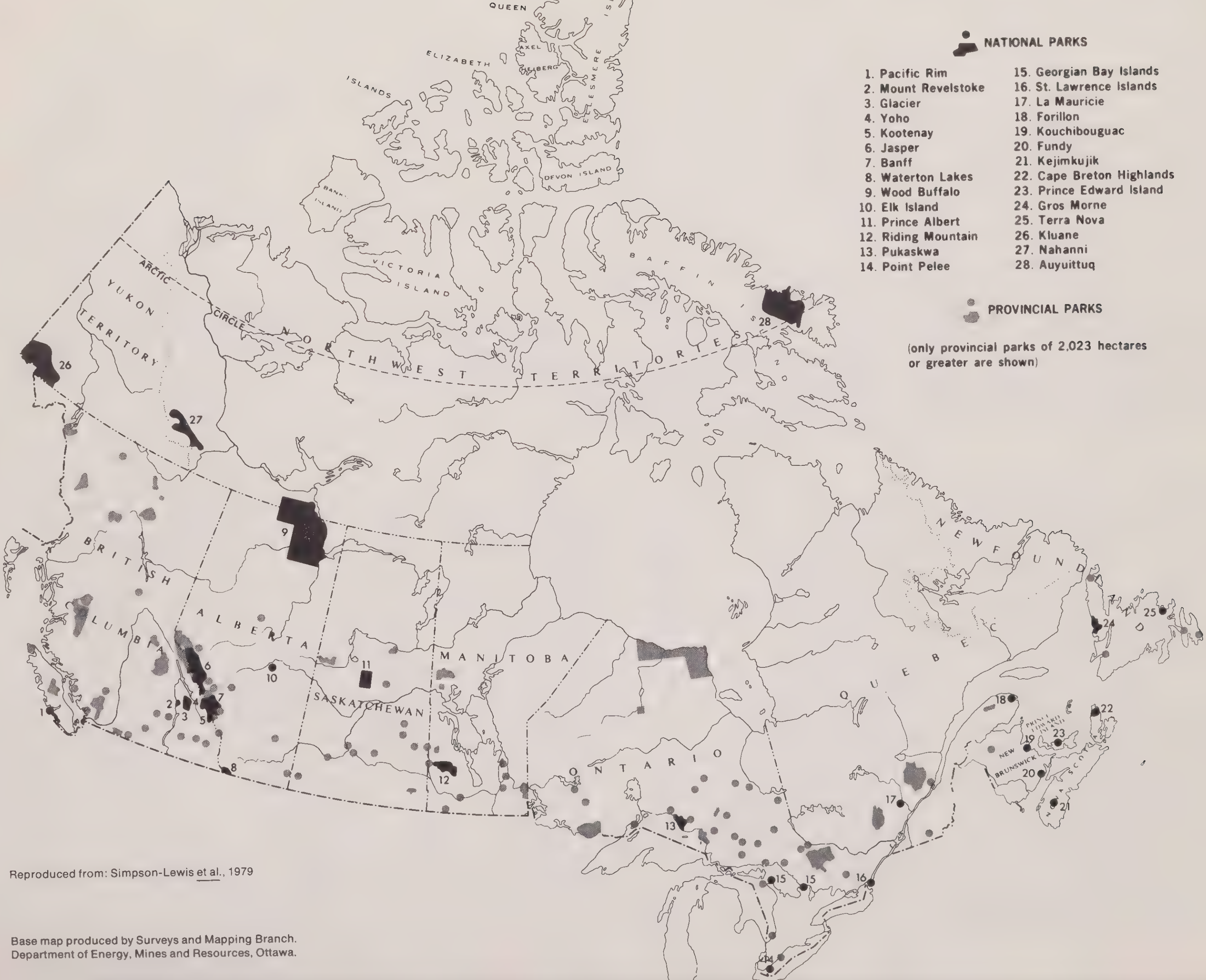
More than 56,878,584 hectares (approximately six percent of the land area) have been set aside specifi-

TABLE 53. WILDLIFE PROTECTED LANDS

PROVINCE/TERRITORY	TOTAL LAND AREA (hectares)	FEDERAL WILDLIFE LAND (hectares)	PROVINCIAL AND TERRITORIAL WILDLIFE LAND (hectares)	TOTAL - FEDERAL PROVINCIAL AND TERRITORIAL WILDLIFE LAND (hectares)
Newfoundland	37,047,225	648	171,836	172,484
Prince Edward Island	565,634	588	4,799	5,387
Nova Scotia	5,283,914	4,225	126,019	130,244
New Brunswick	7,208,987	8,467	308,868	317,335
Quebec	135,674,501	40,241	17,641,827	17,682,068
Ontario	89,116,387	40,084	2,952,703	2,992,787
Manitoba	54,847,607	63	2,898,221	2,898,284
Saskatchewan	57,024,936	73,662	863,714	937,376
Alberta	64,436,712	17,979	904,249	922,228
British Columbia	93,049,668	1,416	922,977	924,393
Yukon Territory	53,182,561	-	1,101,820	1,101,820
Northwest Territories	324,627,908	10,160,188	18,633,942	28,794,130
Canada	922,066,040	10,347,561	46,530,975	56,878,536

Source: Simpson-Lewis et al., 1979.

MAP 21. MAJOR PARKS IN CANADA



Reproduced from: Simpson-Lewis et al., 1979

Base map produced by Surveys and Mapping Branch.
Department of Energy, Mines and Resources, Ottawa.

MAP 22. WILDLIFE PROTECTED LANDS

Note Wildlife Protected Lands are defined as lands whose primary function is the management of wildlife Included are migratory bird sanctuaries, national wildlife areas, wildlife management areas, game reserves, etc With the exception of Polar Bear, Quetico and Killarney provincial parks in Ontario, no other national or provincial parks have been mapped

Reproduced from Simpson-Lewis et al 1979

Base map produced by Surveys and Mapping Branch Department of Energy, Mines and Resources, Ottawa.

TABLE 54. STATUS AND SIZE OF IBP SITES.

PROVINCE/TERRITORY	AREAS WITH PROTECTED STATUS[1]		AREAS WITH NO PROTECTED STATUS		TOTAL	
	Number of IBP Sites	Size (hectares)	Number of IBP Sites	Size (hectares)	Number of IBP Sites	Size (hectares)
Newfoundland	18	352,160	49	302,006	67	654,166
Prince Edward Island	11	9,481	62	12,980	73	22,461
Nova Scotia	11	726	17	8,150	28	8,876
New Brunswick	3	119	12	3,056	15	3,175
Quebec	-	-	25	52,375	25	52,375
Ontario	156	776,727	323	104,848	479	881,575
Manitoba	34	1,038,985	36	116,872	70	1,155,857
Saskatchewan	24	353,381	76	1,189,150	100	1,542,531
Alberta	147	2,511,587	50	111,420	197	2,623,007
British Columbia	43	116,199	173	499,474	216	615,673
Yukon Territory	2	44,000	10	1,155,389	12	1,199,389
Northwest Territories	5	967,390	33	1,611,239	38	2,578,629
Canada	454	6,170,755	866	5,166,959	1,320	11,337,714

Note: 1. Area designated as having "protected status", may include federal and provincial wildlife refuges, national and provincial parks and ecological reserves. Sites with both a "protected" and a "non-protected" portion are considered as "areas with some protected "status".

Source: Simpson-Lewis *et al.*, 1979.

cally for wildlife protection (Table 53, Map 22) in over 600 individual protected areas. The tendency to add to the protected lands category has not diminished. The International Biophysical Program, subcommittee on Conservation of Terrestrial Biological Communities has co-operated with provincial governments in establishing over 454 sites with protected status and 866 without protection, affecting some 11,337,714 hectares (Table 54).

The non-protected, public or scientifically supported category illustrates the case of a special status being accorded a piece of land for its unique qualities, but not entitled to any particular legal protection. However, it would be defended against suggestions for changes of land use by their custodians and by public opinion. Similar cases would be unique historical or archeological sites owned by private persons or groups, but informally recognized as being of special environmental value.

Indeed, further indications of the importance of this category can be found in proposals for three types of new protected lands in a recent Parks Canada (1979) policy document. They include: (i) Canadian Heritage Rivers representing outstanding examples of the major river environments of Canada, (ii) Canadian Landmarks System protecting exceptional natural sites, and (iii) Heritage Buildings, representing Canadian architectural and cultural heritage. However, following a surge of new National Parks in the late 1960's and early 1970's, the rate of dedication of new parks of any type has declined significantly and is not expected to change in the foreseeable future. The only one likely to be established in the near future is the proposed "Grassland National Park" in Southern Saskatchewan covering some 815 square kilometres.

A category not directly related to preservation but nevertheless in the restricted access category are Federal military bases and reserves. These account for a further 1.85 million hectares of land (Swan, 1978).

INDIAN RESERVES AND NATIVE CLAIMS

The second major category of protected lands are those associated with the native peoples of Canada. In treaties signed between 1871 and 1923, native Indians gave up any further claims to lands in northern Ontario, Manitoba, Alberta, Saskatchewan, the northeastern part of British Columbia, and part of the Northwest Territories by transferring them to the Federal government. In return, these Indians received annuities and specific areas of land reserved for their use.

However, major land areas not covered in the treaties included northern Quebec, the Yukon Territory, and most of British Columbia and the Northwest Territories. It is precisely these land areas which have come under

MAP 23. COMPREHENSIVE NATIVE CLAIMS IN CANADA

LEGEND

Apart from the James Bay "Territory", the areas indicated on this map represent only approximate boundaries of the areas in which the various native associations have claimed an interest. The precise delineation of these areas for each claimant group will be determined as negotiations proceed on the separate claims settlements.

- (1) Council for Yukon Indians (CYI)
- (2a) Western Arctic Region
- (2b) Committee for Original Peoples' Entitlement (COPE): land areas selected by COPE pursuant to the COPE Agreement-in-Principle
- (3) Dene Nation
- (4) Metis Association of the Northwest Territories (MANWT)
- (5) Inuit Tapirisat of Canada (ITC)
- (6) Labrador Inuit Association (LIA)
- (7) Naskapi-Montagnais Innu Association (NMIA)
- (8a) James Bay Agreement "Territory" (Grand Council of the Crees of Québec & the Northern Québec Inuit Association; Naskapis of Schefferville)
- (8b) Land areas selected by the Crees and Inuit of Québec pursuant to the James Bay and Northern Québec Agreement
- (9) Conseil Attikamek-Montagnais
- (10) Nishga Tribal Council
- (11) Kitwancool Band
- (12) Association of United Tahltans
- (13) Gitksan-Carrier Tribal Council
- (14) Kitamaat Village Council (Haisla Nation)
- * Proposed National Wilderness Park, Northern Yukon

Source: Dept. of Indian Affairs and Northern Development, 1980 b.

the steady pressure of resource development projects and attendant non-native settlements. Demands for formal recognition of aboriginal interest in these lands, and compensation for its loss led, in August 1973, to a Federal government policy statement on claims of Indian and Inuit people (Dep. Indian Affairs and Northern Development, 1973). The policy follows, in essence, the traditional recognition by the colonial, provincial, and national legislatures that native people as prior residents of the land had certain types of rights in relation to that land. In summary, the 1973 policy provided the following basic elements.

(i) It reaffirmed that lawful obligations to Indian People arising out of existing treaties must be satisfied through the negotiations of "specific claims". In other words, the government would continue to recognize grievances that the native people might have about its administration and the effect it may have on Indian and reserve lands.

(ii) It recognized the existence of native interests in some parts of Canada, (mainly N.W.T., Yukon, Northern Quebec, B.C.) which have not yet been extinguished by treaty or superceded by law. These are to be settled through the negotiation of "comprehensive claims" settlements. (Settlement can consist of many elements, such as lands; cash; hunting, fishing, and trapping rights; and special environmental protection regimes.)

(iii) It created a special federal office, the Office of Native Claims in DINA to serve as a point of contact with the natives and as an interdepartmental co-ordinating body to facilitate the settlement of both the "specific" and "comprehensive" claims.

The most-significant comprehensive claims in terms of area, by native associations are indicated on Map 23. The areas indicated represent only approximate areas of interest to the various native associations. Some of the important issues at the heart of the comprehensive settlement claims will effect access to, and the nature of, new developments permitted in land areas under question. They are as follows:

(i) Demands for special hunting, fishing, and trapping rights for all species of wild fauna including fish, marine mammals, and migratory birds (central to all native land claims).

(ii) Environmental protection over lands owned in fee simple by natives.

(iii) Mitigation of and/or compensation for environmental damages resulting from development activities.

The first comprehensive claims settlement under the new policy was the James Bay and Northern Quebec Agreement on November, 1975 (came into law, October, 1977). The Cree's obtained outright ownership to 7,735 square kilometres and exclusive hunting, trapping, and fishing rights to another 62,096 square kilometres. The Inuit received outright ownership to 8,030 square kilometres and exclusive hunting, trapping, and fishing rights to another 82,530 square kilometres to deal with the mitigation of and/or compensation for environmental damages resulting from development activities the agreement contains a detailed legally enforceable Impact Assessment and Review Process, in which the natives play a strong advisory role at all stages of decision-making. The emphasis is on identifying potential damage before it is done. Precautionary and remedial measures are determined before the development is allowed to proceed. In some cases, natives are to be compensated through land replacement. All the native lands in northern Quebec owned in fee simple were made subject to all applicable environmental laws of general application.

The problem of environmental controls over the lands that will be eventually owned in fee simple by natives is a sensitive one. The problem arises from the fact that in the North, most environmental and land use controls do not apply to privately owned land. At the moment, this is a minor problem because very little land is privately owned. However, it is already clear that as part of future claim settlements, somewhere between 129,495 to 181,295 square kilometres of Canada's Northern Territories may be owned in fee simple by natives and as a result may no longer be subject to existing environmental controls (as they are currently enacted) such as the Territorial Land Use Regulations or the Federal Environmental Assessment Review Process. While some might argue that native groups are particularly environmentally conscious, and consequently very suitable stewards for these lands, it must also be pointed out that as prime benefactors from the development of these lands they would be in the same position of potential conflict of interest as the Department of Indian Affairs and Northern Development presently is, i.e. having the dual responsibility for development and environmental protection.

Native people are very conscious of the fact that, by their own choice, they may inadvertently precipitate the deterioration of the environmental and wildlife productivity, and hence, the opportunity to continue their traditional way of life. They therefore propose, in most claims, some sort of a legally enforceable process whereby the environmental impact of development

activities are identified, mitigated, and, in the case of environmental deterioration and/or losses, compensated for. However, the process of negotiation and settlement is extremely slow, and in the interim, considerable pressure and, in some cases, antagonism can be built up between proponents of resource development, native groups, and conservationists. The degree to which government, resource groups, and native associations can efficiently and effectively move through the negotiation process will dictate the extent to which interim problems (or conflicts) arise.

SIGNIFICANCE TO MINING

Although mining developments may not come into contact with a park, wilderness zone, Indian reserve, or native settlement, the suggestion of potential harm to the environment may be enough to arouse questions

Abandoned cesium mine, Bernic Lake, Manitoba
NFB — Phototheque — ONF, Chris Lund

which may delay, or even exclude, exploration and development. We are only now beginning to see the magnitude of long-term effects of certain management practices. Our limited knowledge of the long-term capacity of the earth to absorb disturbances, certain wastes, or airborne contaminants in any medium has raised doubts and fears about the location of new mines, smelters, or refineries. Therefore, the mere presence of one of the above-mentioned protected areas in a drainage basin or downwind from a proposed mine development is sufficient to arouse considerable opposition, demand for a public inquiry, or outright exclusion. Thus, protected or limited-use lands can play a role disproportionate to their actual size, due to their multiplicity and wide distribution. They can, and have, become important factors influencing mine developments. In the case of native groups, a new development can become the focus of attention of much-wider land claims issue.

The mining industry in Canada has been concerned with what appears to be a trend towards increased land withdrawals from any use whatsoever, or the banning of exploration and development activities from certain lands. The Western Miner (1979) cited the series of injunctions and land use regulations restricting mineral exploration on 130,000 square kilometres in the Baker Lake region of the Northwest Territories, along with government proposals for six wilderness parks that could put about 50 percent of the Northwest Territories off-limits to mining companies. Added to this is the withdrawal of 38,850 square kilometres of the northern Yukon for a Wilderness Park in mid-1978 (Redpath, 1979). The most-recent case has been the seven-year moratorium placed on uranium exploration and mining in British Columbia. As stated by Premier William Bennett: "it is clearly the mood of the people of this province that they are not prepared to live with uranium mining at this time" (Williamson, 1980).

Proponents of unrestricted access to land by mining believe that:

"Most exploration techniques have zero environmental impact; drilling can be of slight temporary impact, less for intrinsic reasons than because of the need to construct roads or helicopter pads in remote localities. Trenching, pitting and shaft exploration can be intrusive but, even when carried out intensively, can easily be remedied by appropriate restoration; the underlying motive seems to be that mining might follow, it is better not to know what lies in the ground." (Minerals and the Environment, 1980).

The argument supporting unrestricted access is that effective land use planning and management can only be made once all the resource potential has been confirmed. The industry questions the arbitrary assigning of "values" to wilderness areas and parks, etc., without any consideration of the potential mineral value. It would appear to most proponents of mining developments that:

". . . banning of mineral exploration — is nothing less than an admission that if mining proposals do follow, the legal and administrative machinery is inadequate to enable the full and mature assessment of the merits of mining in relation to the merits of wilderness areas." (Minerals and the Environment, 1980).

A recent Canadian government background paper on Industry and Government Relations and Mineral Issues confirms that the mining industry is demanding that only the most extreme reasons should prevent access to land for exploration (Jeffery, 1981).

The dilemma facing the various levels of government in Canada is how to balance the overall needs for resource development with the demand for conservation and protection. Some workable mechanism for trade-offs among the various interested parties is still necessary. This requires the very difficult task of reconciling the multiple objectives of a wide range of agencies and departments among the varying levels of government. The task is going to become increasingly difficult as pressure for more parks, wilderness areas, increased environmental protection, and native claims coupled with the demand for mineral and energy resources continues to accelerate in the next two decades. Jurisdiction and land allocation will continue to be the focus of attention for all parties concerned, and the determining factors in any attempt to reconcile competing demands on land resources.

PUBLIC PERCEPTIONS AND ATTITUDES

Continued demands on Canada's limited land resources raise the question of the collective effects of man's activities. Concern usually focused on the broader implications of irreversibly committing land resources to consumptive uses for example, housing, industrial energy, mining, transport, and waste disposal. Normally, productive land uses such as agriculture and forestry were considered non-consumptive in terms of the land resource, but evidence today reveals that this traditional split between consumptive and non-consumptive uses has become blurred and is no

longer valid. Deterioration of the traditional non-consumptive land-resource base has raised new fears and stresses. Even recreation and tourism based on non-consumptive values of aesthetics, scenery, wildlife, forestry, and quiet open spaces is under increased pressure and deterioration from its own momentum. Despite the relatively small percentage of land converted into consumptive uses the cumulative effects now reach beyond their immediate boundaries to create a far greater influence and impression on the public. The public is becoming more sensitive and more aware of land use and the results of mistakes in past land use decisions. While land managers and planners are more sensitive to the risk of repeating past land use mistakes and creating new ones.

Public perception of these developments is reflected in their concern over the loss of agricultural land, depleting forest and energy resources, the rising cost of land and housing, native claims, and the degradation of destruction of ecologically sensitive areas that have continued to persist as important public issues. Many individuals and groups are now questioning previous and impending decisions regarding the allocation of land resources. Their ability to do so has been enhanced by the increasing use of environmental impact assessment procedures, public inquiries and Royal commissions. The introduction of a wide range of land use regulations and zoning mechanisms has ensured a continuous focus on one land issue or another throughout the past decade at all levels of government. The increasing attention of the media — newspaper articles, letters to the editor, radio and T.V. forums — on these public inquiries and controversial government land use decisions has served to increase this public awareness and involvement.

Woodrow (1980) indicates that the slow moving conservation movement of the post-war period gained momentum and gradually merged with the environmental movement of the late 1960's and early 1970's. High rates of urban growth in the 1960's and 1970's coupled with rising salaries, mobility, more leisure time, and increased access have increased the demand for more pristine environments with high values placed on outdoor recreation. The rapid urban growth stimulated this great interest in pollution control and environmental protection. So much so that today conservation and environmental organizations play an increasingly important role in shaping public attitudes and images towards changes in the use of land. The environmental movement now comprises well in excess of three hundred societies and organizations in Canada (Clements, 1974). Many are extremely well organized and increasingly visible at the national level. Their very names imply vested interest and concerns — Agriculture Institute of Canada, Canadian Forestry Association, Canadian Arctic Resources Committee, Canadian Wildlife Federation, Canadian Environmental Law Association, and Canadian Parks and Recreation Association — in one segment or another of our natural resource base. Indeed, many more local and regional groups arise in response to a particular development or change in land use only to disappear once the issue has been settled. Many of these organizations have established links with others, ranging from consumer and native rights groups to trade unions, on a wide range of environment and resource issues of shared interest and concern. Under the circumstances, it is not surprising that decisions reconciling environmental problems arising from major new development proposals will be increasingly influenced by the interplay of these pressure groups at public inquiries or environmental assessment reviews.

Remembering that the amount of land directly disturbed by mining activities is extremely small, it may be questioned whether mining is receiving attention out of all proportion to its size. The area involved seems insignificant when compared to the overall size of the country, and the amount of land devoted to other consumptive land uses. However, more than half of all the lands directly disturbed or utilized by mining activities are located in and around urban centres so that potentially they influence a population out of all proportion to its size. More than seventy-five percent of the population is located in urban centres. Thus every hectare of land disturbed by mining — pits and quarries in particular — is a far greater eyesore than the thousands of hectares disturbed in the more-remote uninhabited areas of Canada. It is not surprising that the "not-in-my-backyard" syndrome can sometimes play a very important role in the public's perception of not only the mining industry but unpleasant essential services such as garbage dumps, and disposal sites for toxic chemicals and wastes. No one wants facilities of this nature near, or in, his neighbourhood. Fear of depressed land values by adjacent owners play a significant role in this process. Planners have estimated that one hectare of disturbed or derelict land may create ten hectares of a "gray zone" (shadow effect) around it (Goodman and Bray, 1975).

In this regard, a major problem facing the mining industry in the future is its unfavourable public image. Past perceptions of mining and its environmental impacts appear to be permanently etched in the minds of the general public. It appears that the mining industry's attempts to improve its image and the public's understanding of its activities has progressed only mar-

ginally. It is this general perception of mining as a singular source of land degradation and pollution that has caused so much attention to be focused on it, in the form of government regulation or restricted zoning. The industry continues to be confronted with its image every time it enters a public debate or inquiry. Now that it is almost mandatory that evironmental impact assessment and public hearings occur prior to any new mine development, public perceptions are playing an increasingly important role in the decision-making process.

The standards for all new developments have continued to become more stringent, since the quality of life as well as the environment have become increasingly important social and economic issues. The situation today has become considerably more complex as socio-economic and political issues become merged with the more-traditional conservation and environmental issues. The links between resource developments, the environment, life styles, and institutional values can no longer be ignored.

At the recent hearings of the British Columbia Royal Commission inquiry into the Health and Environmental Protection in Uranium Mining (1980), some of the major issues raised were identified as follows, according to the number of times mentioned (in brackets):

(i) Waste management, and its long-term storage and disposal (85);
(ii) Health; effects of radiation (81);
(iii) Land use conflicts and their adverse economic impact (62);
(iv) Lack of faith in government and regulating standards (60);
(v) Lack of public access to information (55);
(vi) Commercial interests *versus* human concerns (52);
(vii) Poor past record; in both mining and government (46);
(viii) Enforcement and regulation problems (31).

It is evident that the scientific community, regulating authorities, and elected officials also suffer from a lack of trust and a greater demand for public involvement in decision making.

The views of all the various pressure or lobby groups have become highly relevant within their own frame of reference, since there is no absolute way of measuring the relative importance of different environmental problems. Of overriding importance is the way in which individual decision makers and pressure groups perceive the situation with which they are confronted. The extent to which they diverge on issues may determine whether or not any decision is achieved. Differences in perception can occur on a personal basis or on up through various levels of authority and society on a local, regional, provincial, or national basis, and associations or pressure groups, although sincere, are often partisan by nature.

An example of the power of these forces is revealed in the attempts of Eldorado Nuclear Ltd. to establish a new uranium-hexafluoride refinery. In 1975, the company began examining the feasibility of locating a refinery in Saskatchewan. Of the original 14 sites examined, Eldorado chose a site near Warman as the most likely prospect. The actual site is located 23 kilometres northeast of Saskatoon in the rural municipality of Corman Park, 5 kilometres southeast of Warman, and 2 kilometres west of the south Saskatchewan River. The proposed site is located in an agriculturally productive area and one of the largest and oldest concentrations of Mennonites in Saskatchewan.

Eldorado Nuclear Ltd. as a proprietary Crown Corporation usually submit their proposals to the Federal Environmental Assessment Review Process. Guidelines for conducting an environmental impact assessment were issued in June, 1976. In October, 1979 Environment Canada formed an environmental assessment panel to review the impact statement prepared by Eldorado and receive submissions from all interested parties. Formal public hearings began in January, 1980, when a total of 336 people appeared before the panel and an additional 201 submitted written briefs. (Environment Canada, 1980).

Fully a third of the organized groups or associations making verbal and written presentations were affiliated with various religious faiths. In August, 1980, the panel released its report stating that it could not endorse the Eldorado Nuclear Ltd. refinery proposal in its present form. The panel found the site acceptable with regard to the potential effects on the environment but it was unable to support the proposal because of the uncertainty about the social effects on nearby residents (Environment Canada, 1980). More specifically they cited the lack of information on the refinery's possible negative effect on the Mennonite community around Warman. The panel recommended that before any decision is made, one of the following three options be considered:

"(i) Further information be provided by the proponent with respect to the potential social impacts of the Warman proposal, with subsequent public review.

(ii) One or more alternative sites in Saskatchewan be selected and evaluated with regard to social and environmental impacts and submitted for public review.

(iii) One or more sites in Saskatchewan be evaluated and reviewed in comparison or conjunction with the Warman site. This would be a combination of options 1 and 2." (Environment Canada, 1980).

Furthermore with regard to option one, the panel considered the following information essential before a refinery could be established at Warman:

"(a) The extent to which the presence of a nuclear refinery may erode religious beliefs of residents of the community and the likely consequences.

(b) Interpretation of the concept of stewardship and the extent and depth to which this concept occurs locally, the degree to which it may serve to bind the community, and the impact of the refinery particularly with respect to radioactive waste disposal.

(c) The effects of increased contacts between outsiders and the local community that are occurring in the light of recent social trends, and the effects of a refinery. This should then be related to impacts on social and cultural activities of the ethnic communities.

(d) The degree to which the proposed refinery would result in reduced control of local institutions which may be an essential part of the ethnic and religious communities.

(e) The effect the refinery may have upon the transition zone which appears to exist between the Saskatoon urban society and the local religious/ethnic group.

(f) The role the refinery may play in checking or stimulating changes, underway, in family structures and kinship contacts.

(g) The changing occupational structure of the labour force in the local community and the impact the refinery may have.

(h) The extent to which agrarian activities are a major underpinning of the local community upon these activities." (Environment Canada, 1980).

In a newspaper interview after the panel decision, the vice-president in charge of nuclear refining for Eldorado expressed the Company's concern over the changing guidelines of the panel, particularly the fact that there was no requirement for religious or other beliefs of the local population to be investigated (Humphries and Rusk, 1980). He went on to say that the company was baffled on how to deal with these social issues, and "I'm not sure how anyone can determine most of these perceived impacts. In almost all of the issues raised today, the judgement would have to be subjective. I know of no criteria on which they can be judged subjectively".

The Saskatchewan Environmental Advisory Council's (1980) annual report for 1979-80 pointed out that the:

". . . Warman hearings dealt more with impassioned idealogical exchanges than an objective assessment of the proposed project... Irrespective of the quality of the presentations made, the majority of these submissions addressed issues which were outside the terms of reference specified for the assessment panel".

In the five years between the issuing of the Environmental Impact Assessment Guidelines and the Environmental Advisory Panel's final report, neither the company nor the panel could have anticipated the degree of opposition and the direction it took. Nor did the potential impact on, and loss of, agricultural land become the major concern as anticipated. Socio-religious concerns became entangled with the broader anti-nuclear movement, thus widening the review beyond the local and regional setting. When dealing with the word "uranium", it has become so closely associated with the nuclear reactor side of the industry that often waste problems of mine and milling operations are lumped together with refinery and end-use reactor operations in public debates. In fact, the assessment panel spent the better part of the hearings listening to submissions on ethical and global aspects of the nuclear industry, issues which it had no mandate to address (Saskatchewan Environmental Advisory Council, 1980).

A similar attempt by Eldorado to build a refinery at Port Granby, Ontario was rejected principally on agricultural grounds (Environment Canada, 1979e). The proposed refinery in this case would have been on high-quality agricultural land and in conflict with regional plans. There was already considerable opposition to, and concern about, the continued loss of high-quality farmland in Southern Ontario in general. It was felt that once initiated, the trend away from agriculture would be like a chain reaction with consequential effects on land costs, lifestyles, and the general character of the area (Environment Canada, 1979e).

Although the uranium refinery case is an unique example, it is indicative of the situation prevalent today with regard to new development proposals. It is evident that those responsible for the Environmental Impact Assessment will have to pay more attention to, and define more carefully, the socio-economic and lifestyle requirements to be investigated. The whole process had tended to be heavily weighted towards ecological ramifications. Nor can the agencies responsible for the review and the individual proponents of proposed new developments concentrate on a single site, while ignoring possible alternatives. Even though the costs of conducting a single impact assessment and carrying it through the public hearing process are considerable, failure can be even costlier in terms of time delays by not having an alternative prepared. While this comment may apply to some beneficiation and most refinery situations, they do not apply to proposed new mineral extraction sites where there is rarely any alternative.

In the case of inquiries into new mining developments, often the reconciliation of interests proves impossible, or some form of compromise is required that results in the loss of some aspect of the resource base. This is particularly true of mines located in sensitive wilderness of wildlife habitats, areas of special protected status of high recreational value, and prime agricultural lands. The Commission on Mining and the Environment in the United Kingdom (United Kingdom, 1972) outlined the dilemma that results from environmental inquiries, concerning any new development as follows:

"There are some who contend that a distinction could be drawn between sites which either because of their archaeological or historic past, or because of some unique ecological characteristic cannot be restored or replaced once they are developed, and areas whose particular scenic character could in theory be recreated, relocated or matched, given the necessary skill and resources and given sufficient time. Others deny this and would refuse to admit the possibility of providing an acceptable replacement for an existing outstanding view, even allowing for all the known skill of modern landscape renewal techniques.

"It seems that any attempt to differentiate some areas where mining could take place into two such categories would be doomed to failure because of the considerable diversity of the environmental and amenity interests that are encountered. At one extreme we could find the local enthusiast who might claim that some species of wild plant is a supreme rarity which would disappear if the area in which it grew were developed. Here authoritative scientific advice could be called upon either to support or to refute such a view. At the other extreme would be the individual who might protest that any development would destroy an unsurpassable view from his window. No authority, however eminent, could deny him this opinion if he insisted on maintaining it. When dealing with environmental matters, we have clearly to accept that we are faced both with matters of fact and with questions of value. The former can usually be resolved. Arguments about taste cannot. That is the dilemma by which we have constantly been faced during the course of our enquiries".

It is no longer possible to treat problems confronting the natural environment in isolation from the socio-economic and political environment. Environmental problems are rooted in society and the institutions which serve it. Here the linkages between development, the environment, life styles, and institutional values will have far-reaching consequences for all future mining developments. The limits within which governments and other actors must operate will often be determined by popular attitudes and opinions. Neither is it likely that independent, unbiased technological assessments of the environment, nor cost-benefit studies will suffice to permit future developments.

LAND USE CONFLICTS

Mining land use problems and conflicts in Canada often fall into one or more of the following generalized categories:

(i) Conflicts that arise when two or more proponents compete for the same parcel of land, for example, coal strip mining and agriculture in the western prairies of Saskatchewan or Alberta.

(ii) Conflicts that arise when a particular land use on one parcel of land adversely affects the use of land on adjacent properties. This usually raises the question of compatibility or incompatibility of uses, for example, the impact of metallic mine wastes on the use of neighbouring water resources, fishing in particular.

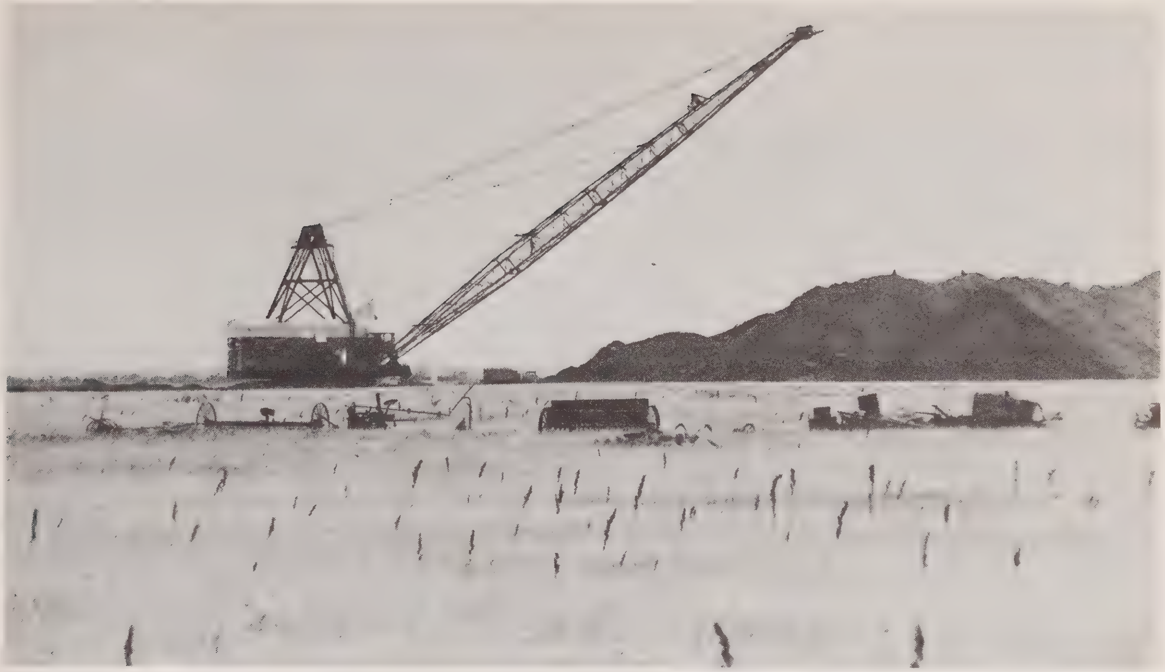
(iii) Conflicts that arise between those who wish to develop a particular mineral or energy resource and those who desire the maintenance of a pristine environment, through conservation and protection, for example, the establishment of parks or wilderness preserves.

These categories are not mutually exclusive, often two or even three of them can be involved in any given issue or conflict. This occurs more and more frequently in recent years with the increased use of environmental impact assessments and public inquiries. Ownership and jurisdiction are the two factors determining the means with which one deals with land-use conflicts. Hence, land allocation and the management of land resources can further complicate any conflict or issue. In fact, interagency or intergovernment jurisdictional problems can add to difficulties in solving conflicts or become the potential source of a conflict itself.

COMPETITION FOR THE SAME PARCEL OF LAND

Some of the strongest cases of competition for the same parcel of land occur between proponents of new mine developments and farmers on existing agricultural lands. This is especially evident where relatively shallow, flat, or gently dipping deposits of coal are present. Characteristic of this type of conflict was the attempt to establish the ***Camrose Riley Power Project*** southeast of Edmonton, consisting of a coal mine at Roundhill and a thermal-generating station at Dodds. The mine site proposed was in the centre of some of the finest agricultural land in Alberta. In the period between 1982 and 2026 A.D., a total of 14,165 hectares would eventually be stripped, although never more than 1,335 hectares at any one time. In addition, the thermal plant would require a permanent disturbance of 1,215 hectares for the cooling ponds and source water would have to be piped in 95 kilometres from the North Saskatchewan River. The proposed thermal station would have been the largest in western Canada, with an installed capacity of 225 MW. Opposition to the proposed development came from 125 affected families on the grounds that the strip mining would permanently damage a large, viable farm area and that, to date, no one has proven that the land could be reclaimed to pre-mining crop production levels. At the time (1976), the province's new "Coal Development Policy" demanded proof that the land could be reclaimed to its former level of crop production. Furthermore, farmers' concerns about disturbances to the ground-water regime and the inability to deal with adverse layers of soils (sodic tills and bedrock materials prevail throughout the southern prairies) in the reclamation process added to uncertainties. In addition, the local member of the provincial legislature raised the issue of the need to preserve the more-productive agricultural lands of Alberta for what would be serious world demands for food in the next fifty years (Globe and Mail, 1976). He felt that, in the long run, the earnings generated from agricultural production would be of greater benefit. All opposition groups to the mine contended that there were many other economically stripable coal deposits on less productive lands that should be considered first. Indeed, many other towns expressed interest in the project. The Camrose Riley project was the first test case under the new "Coal Development Policy" (Alberta, Government of, 1976). Under the pressure of protecting the long-term viability of the agricultural lands, the project was rejected in the fall of 1976. The province approved as an alternative the extension of an existing mine in the Keephills areas to the southwest of Edmonton in November, 1976. At the time, there was still very little evidence that coal-stripped lands could be reclaimed successfully to former production levels. The province was only beginning to see the first evidence of the effect of its new Lands Surface Conservation and Reclamation Act (1974) on currently operating mines and through its own programs to clean-up past disturbances. The focus of reclamation research was still on revegetation and not on selective materials placement and restoration of drainage and aquifer systems which were to be initiated in the latter half of the 1970's.

The allocation of land to strip mining will be a potential long-term problem in Alberta in view of the fact that 49 percent of all coalfields in the province are found under existing agricultural lands. But, more importantly, 63 percent of the coalfields are in the central and southern plains areas (LRZ II-3), two-thirds of which are located under arable lands classed 1 to 4 (CLI—Agricultural capability), accounting for 523,270 hectares of land (Hermans and Goettel, 1980). They estimate that up to 13 percent of this total could be disturbed if all the proposed coal developments (for thermal-power generation, and gasification and petrochemical industries) were to proceed in the next 25 years. These figures do not include additional land requirements for infrastructure — haul roads, rail spurs, expanded community services, ancillary industries, etc. — which would increase the figure a further 50 to 100 percent. The key to the successful expansion of strip mining will be whether or not reclamation technology can improve sufficiently to reclaim disturbed agricultural land to its previous state. The province has focussed on this problem as a research priority and, in the interim, many areas have been excluded from development until there are viable solutions. An integral part of the conflict over the development of agricultural lands is the industry's viewpoint that the concept of reclamation defined in the Land Surface Conservation and Reclamation Act does not allow enough flexibility in reclaiming former agricultural



Coal strip mining, Estevan, Saskatchewan
NFB — Phototheque — ONF, Crombie McNeill

lands. This may become an important issue in the future if reclamation research fails to develop a successful cost-effective procedure to return agriculture land to its former level of production. In the meantime, many of the existing coal developments have been allowed on the premise that the land can be reclaimed to its former state. To date, experience in reclaiming strip-mined lands back into crop production is still limited.

The problem of reclaiming lands disturbed by coal mines is not unique to Alberta. Similar difficulties will be encountered at the Estevan fields in Saskatchewan (*see* the Poplar River Site, Chapter 5). Reclamation research conducted on disturbed sites in the alpine areas of northeastern British Columbia indicates that the ability to restore vegetation above the tree-line will be exceedingly difficult without continued use of fertilizer (Errington, 1979).

On a larger scale, proposals for "***Grasslands National Park***" in southern Saskatchewan are still under negotiation between the Provincial and Federal governments. The park is proposed in two parts, one block near Val-Marie and a second at Killdeer, connected by a parkway and covering 85,470 hectares at its maximum. However, before the province can commit such an area to essentially a conservation and recreation complex, land containing known significant coal reserves has been excluded from the proposed park, and a detailed oil- and gas-drilling program has to be completed in the west block before any further action will be forthcoming. The long-term planning precautions taken by the province were necessary in the light of past experience with parks or wilderness reserves in Canada. No mining is allowed in National Parks, with the exception of localized sand and gravel operations to meet park requirements. It is exceedingly difficult to withdraw protected lands once committed to essentially conservation and recreation purposes for any type of resource development. Hence, the importance of preventing future conflicts over the need to utilize the energy potential of the underlying coal, oil, and gas.

Unlike coal mining in the Prairies, ***the aggregate industry*** (sand, gravel, and crushed stone) finds itself in a much greater dilemma due to its high visibility and need to be near its major market, the urban centres. Public concerns have been expressed in opposition to excessive truck traffic, noise, dust, vibration, damage to the physical and biotic environment, water pollution, poor aesthetic appearance, and the lack of reclama-

Abandoned sand pit south of Ottawa, Ontario
Robert Audet, Environment Canada

tion.[22] Problem in the aggregate sector of the mining industry originated in the rapid growth of urban centres, particularly in central Canada. Conflicts arose from the competing land use requirements of the aggregate industry, urban (residential, commercial and industrial), recreation, and agricultural sectors of the economy in addition to those conservation and environmental groups advocating complete protection. Some of the most-heated debates on the issue have taken place between government, public, and industrial sectors in Ontario. Over the past decade the province of Ontario has been actively attempting to enact new legislation designed to solve or at least alleviate the most pressing environmental, social and developmental problems associated with aggregate production. Quebec passed its first Pits and Quarries Regulations in 1977 under the Environment Quality Act (1972) in response to similar problems. The regulations require municipal approval and, reclamation within year of cessation of operations, and a security deposit of between $4,000 to $5,000 per hectare.

[22] Problems associated with the aggregate industry have been documented at some length by others: Coates, 1972, 1975, 1976; McLellan, 1971, 1972, 1973, 1975; Yundt, 1969, 1975; and Jewett, 1976, 1977.

Although present conditions in Ontario do not necessarily duplicate those in other provinces, they are indicative of situations which may develop in the more densely populated areas of the provinces (Barnett, 1977). The situation in Ontario provides an excellent example of the ingredients of the problem.

When enacted, the intent of the Ontario Pits and Quarries Control Act (1971) was to provide rules and regulations that would accelerate the rehabilitation and minimize the environmental impact of pit and quarry operations in the province, while at the same time providing assurance that the province's requirements for aggregates could be met by sources within Ontario, (Ontario, Government of, 1977). By the mid 1970's, criticism of the ineffectiveness of the Act and rising conflicts led the Province of Ontario to appoint a "Mineral Aggregate Working Party" to examine the operation of the aggregate industry and the environmental and social concern of the municipalities and public related to aggregate production. The Working Party reported that, five years after the enactment, confrontations still existed and were increasing steadily (Ontario, Government of, 1977).

In the introduction to the Working Party Report it listed its main conclusions, including:

"2. That while there is general acceptance within the province that aggregate extraction is necessary, there is also a very real concern by the citizens involved to see that their interests are protected.

3. That there is concern that consistency be established in the administration of the legislation, in enforcement and in ensuring that demand is met equitably from the available sources within the province.

4. That the government has lacked credibility in performance to date as a result of
1) failure of enforcement
2) weaknesses in the Act
3) little evidence of rehabilitation achievement to date." (Ontario, Government of, 1977).

In order to verify the situation portrayed by the Working Party Report particularly with regard to conclusion 4, the Ministry of Natural Resources contracted an independent assessment of the effectiveness of the Pits and Quarries Control Act (1971). In commissioning the study, the Ministry pointed out "the failure of many operators to properly rehabilitate extracted land is one of the major reasons for current resentment of all those connected with the industry" (Coates and Scott, 1979).

The results of the independent study confirmed much of the situation described by the Working Party Report and went on to conclude that, if current trends continued, the future situation would likely be as follows:

> ***"The simultaneous strip and replace progressive rehabilitation method will be used more widely than at present.***
>
> ***The best work will generally be done by the large operators working on large sites.***
>
> ***Small operators working on small sites will probably continue to treat the security deposit as a tax and not undertake progressive rehabilitation or in some cases not undertake rehabilitation at all.***
>
> ***"Green" uses with demonstrable biological productivity will continue to be the predominant after-uses, but these will be at sub-optimum productivity levels due to lack of interest in proper site preparation, planting techniques and site maintenance, etc...***
>
> ***There will be little improvement in rehabilitation planting techniques and vitality of planting because operators receive little direct financial return on such plantings, because no performance standards are required in legislation, and because little research and communication has occurred between government and industry in this area." (Coates and Scott, 1979).***

The major reasons or motivations for carrying out rehabilitation were identified as: legislation 35 percent; public image 30 percent; and financial gain 20 percent.

Another important conclusion of the Working Party Report was the fact that very little guidance or specific information on rehabilitation methods had been provided by government departments to the aggregate industry in order to comply with regulations. As a result of this criticism, a number of studies were commissioned by the Ministry of Natural Resources to provide more-detailed advice to operators and to develop plans to reclaim abandoned sites (McLellan *et al.*, 1979; Lowe, 1979).

The Working Party Report made 64 recommendations for changes in the Pits and Quarries Control Act (1971) and after a review by a wide number of interested parties the Provincial Cabinet adopted a number of major policy guidelines based on the report and public reviews (Yundt and Messerschimdt, 1979). The policy guidelines formed the basis of the proposed new "Aggregate Act" that received first reading as Bill 127 on June 14, 1979 (Ontario, Government of, 1979), and the more-significant changes are summarized below:

(i) Requires pit and quarry rehabilitation on all private and crown designated lands.
(ii) All licence applications (site plans) must comply with relevant restricted area by-laws.
(iii) All licence approvals by the Ministry must be reviewed within 45 days of Ministry acceptance by the appropriate county or regional municipality. Objections sent in writing to the Minister.
(iv) Annual licence fees will be made available to compensate governments at all levels for costs.
(v) All sites must be inspected and licences reviewed at least once a year. The Act will generally require consultation with municipalities and review of site plans every five years.
(vi) The Minister can now suspend a licence immediately for any period of time, not exceeding three months until the licencee has complied with the notice served upon him. Where the licencee has had his licence suspended and has not taken the required

remedial action, the Minister may revoke his licence.

(vii) An increase in the overall rehabilitation security deposit.

(viii) The Minister may in writing relieve any licencee or permittee from compliance in whole or in part with any provision of the regulations subject to any conditions as he considers necessary.

(ix) The Minister may designate protected aggregate resources zones in the public interest.

Despite the proposed changes introduced in Bill 127 in 1979, opposition continued from the Aggregate Producers Association of Ontario (APAO), municipalities, and a wide range of agricultural, conservation, and environmental pressure groups. The aggregate industry (APAO) is opposed to any control being placed in the hands of regional or municipal governments (Smith, 1977; Interface, 1980; Aggregate Producers Association of Ontario, 1977; Public Sector, 1980). They argue that localized by-law zoning would continue to sterilize vast quantities of aggregates through the use of the Municipal and Planning acts. They want the designation and administration of aggregate producing areas to remain in the hands of the Ministry of Natural Resources, with the Minister having the final decision. They oppose increases in the licence and reclamation fees.

Early public reaction to the Working Party's recommendations continued to reflect the general feeling of mistrust of the government. The "Conservation Council of Ontario's" (1977) brief to the Ministry of Natural Resources pointed out that the report:

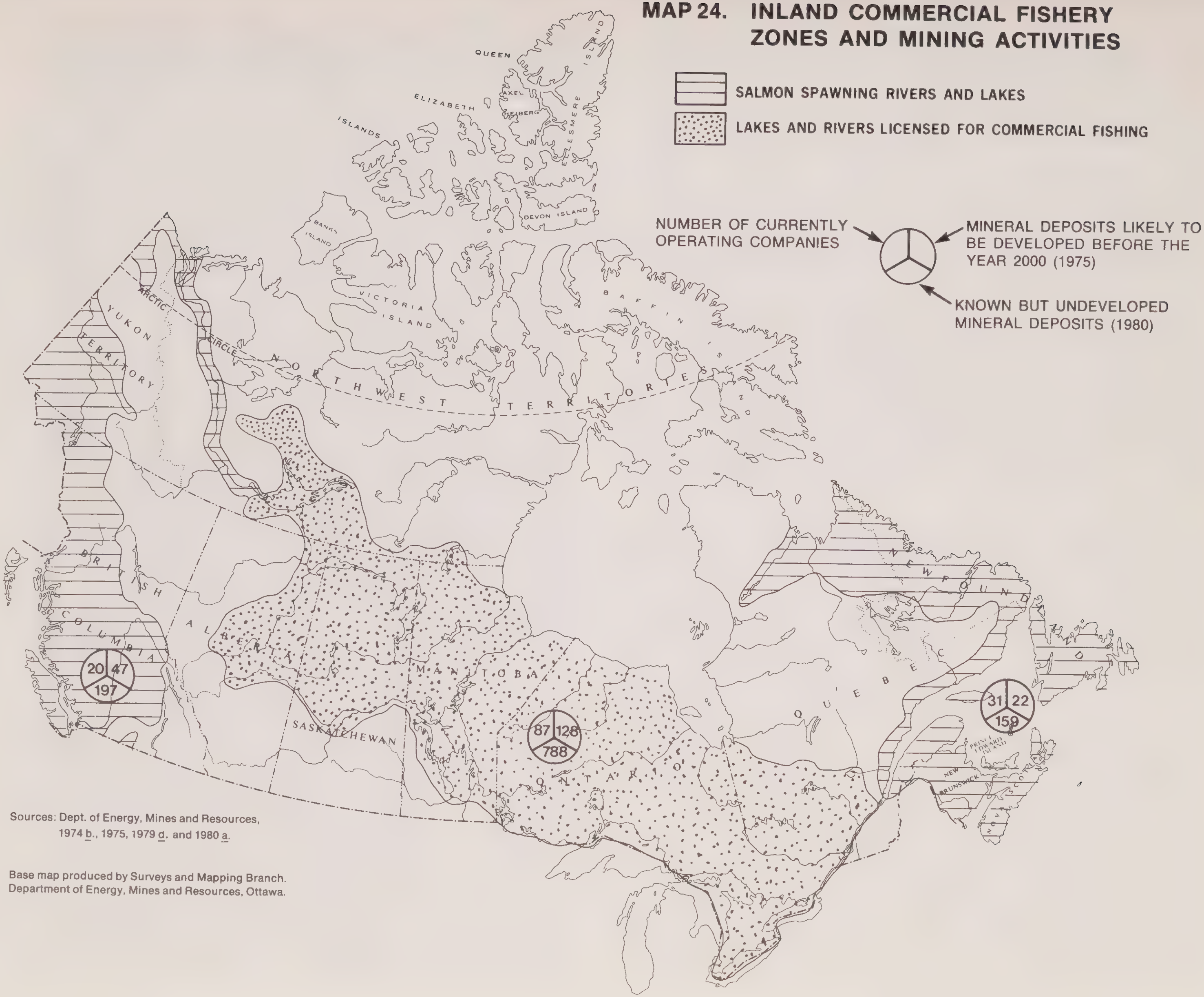
"... is a document whose primary thrust is on locating areas of aggregate and making sure they are not precluded from future use. Its commitment to "ensure that the transgressions and unreasonable trespassing" by the industry should cease is necessary to placate an aroused public. But the recommendations make it clear that these issues are seen as obstacles in the path of orderly aggregate extraction. The equally important issue of protecting key areas against any extraction is largely ignored".

Public criticism continued in the years that followed, but became more specific in response to individual recommendations of the Working Party Report and subsequent clauses of Bill 127 (Muirhead, 1978; Oziewicz, 1980). Local municipalities opposed changes which would give the Ministry of Natural Resources the right to designate large tracts of land for a single purpose — aggregate extraction, as did the farmers affected in key agricultural townships. The feeling was that the proposed primacy of the Aggregate Act over the Municipal and Planning acts would further erode local control through lost zoning powers. The Minister's ultimate authority to ensure that adequate aggregate supplies were available for all regions meant he could intervene in official municipal plans at any time. Environmentalists opposed Bill 127 because there was no provision for environmental impact assessments of proposed new sites or Ministry of Environment involvement in enforcement. Many feared that the same section of the new Act which invalidated the Municipal and Planning acts could also do the same for the Environmental Pollution and Water Resources acts. Unfortunately much of the lack of faith in the proposed revised Act by many groups was the direct result of the poor record of the industry and lack of government enforcement in the past. This despite the fact that they approved and supported the many positive changes in the proposed new Act, including: designating all areas in the province to be under the Act; increased licence and rehabilitation fees; better monitoring and inspection; more-stringent site plans; higher fines for offences; and a rehabilitation fund for abandoned sites (albeit, an inadequate amount to do the job completely).

The opposition to various aspects of the new bill has continued to delay its passage in the legislature. Meanwhile, the Government has introduced some of the proposed changes under the existing Act, by increasing the licence fees to six cents per tonne from two and rehabilitation security deposits to eight cents per tonne from two, as well as designating most of the remaining townships in southern Ontario so that they fall under the Act.

Much of the difficulty in solving this conflict lies in reconciling the authority and jurisdiction between the various departments and the acts they enforce. Particularly the Municipal Act, Planning Act, Environment Assessment Act and specialized planning acts like the Niagara Escarpment and Development Act. This becomes exceedingly difficult in a highly populated region like southern Ontario where the number of interest groups is large, making it almost impossible to reconcile changes in the myriad number of acts and regulations, particularly as they affect land ownership and use. The increasing demand for aggregate resources needs to be balanced with the legitimate land requirements for recreational, agricultural, conservation, and residential uses. But the pressure will continue, since the optimum distance or transporting aggregate is 40 kilometres from its largest market, the

MAP 24. INLAND COMMERCIAL FISHERY ZONES AND MINING ACTIVITIES



Sources: Dept. of Energy, Mines and Resources, 1974 b., 1975, 1979 d. and 1980 a.

Base map produced by Surveys and Mapping Branch. Department of Energy, Mines and Resources, Ottawa.

urban centres. An area with the largest potential number of individual competitors for a given parcel of land of any land resources in Canada.

CONFLICT WITH ADJACENT LAND USES OR RESOURCES

One of the more prominent and widespread conflicts arising out of the effects of one land use on adjacent land uses or resources are those between mining and fishing or the quality of water resources. This is not surprising considering the extent of the river and lake network supporting the commercial and sport fisheries in Canada. Map 24 identifies areas in Canada essential for salmon spawning and those areas licensed for inland commercial fishing. Over three-quarters of the operating mining companies were located within these fisheries zones. Comparison with Maps 12 and 13 (*see* Chapter 3) reveals that an even higher percentage of known, but as yet undeveloped, mineral deposits are located in the same resource zones.

As discussed in Chapter 5 any new mine development could potentially interfere with the availability or quality of water for adjacent and distant areas. Although the use of the land surface itself is not in question a pollution problem emanating from a land-based mine does influence those dependent upon fishing for their livelihood or as a major source of food.

In recent years, just such a situation arose over the discharging of mine tailings into the deep waters of ***Alice Arm in British Columbia.*** The Nishga Tribal Council first raised concerns about the potential harmful effects that tailings might have on their traditional fishing grounds at a Federal — Provincial — Council meeting on native land claims settlements, March 8, 1980. Federal and Provincial permits had been granted to allow Amax of Canada Ltd., a molybdenum mine to discharge waste tailings into the sea at the rate of 12,000 tonnes per day.[23] Concern was expressed about the potentially harmful levels of arsenic, lead, mercury, zinc, copper, iron, cadmium, and toxic radium-226 over the 26 years of the mine's life.

Amax of Canada Ltd. (formerly Climax Molybdenum of B.C.) is currently preparing to re-open the Kitsault mine which is situated in Alice Arm, approximately 144 kilometres north of Prince Rupert, B.C. The Kitsault

[23] Provincial Permit under Pollution Control Board Permit (PE-4335) issued January 12, 1979. Federal Alice Arm Tailings Deposit Regulations by Order-In-Council (P.C. 1979-1112) published in Canada Gazette April 10, 1979. SOR/79-345.

Abandoned sand pit used to dump waste
Robert Audet, Environment Canada

mine was previously operated by British Columbia Molybdenum Limited between 1968 and 1972. Several other mines had operated in the Alice Arm area prior to this period, such as Dolly Varden, Torbrit, and Silver City, which was located near the present townsite of Kitsault. Alice Arm is one of two terminal branches of Observatory Inlet which extends from Portland Canal immediately south of the Alaska/British Columbia border. Alice Arm is typical of most British Columbia glacial inlets — long, narrow, and bordered by high mountains. The deepest point is approximately 394 metres (over 1,200 feet) and a shallow sill is located near the mouth of Alice Arm. The Kitsault River is the main source of natural glacial silt to Alice Arm. Rivers feeding into Alice Arm support stocks of chum, pink, and coho salmon. Various species of groundfish, shrimp, and crab also inhabit the sea bed of Alice Arm, the area most likely to be affected by tailings deposition.

The mill capacity of British Columbia Molybdenum Limited between 1968 and 1972 was approximately 6,000 tons per day. The tailings effluent consisted of a slurry of fine sand-like material. During the period the Kitsault mine operated, roughly 12.6 million tons of tailings were discharged into Alice Arm. Molybdenum analysis of the surface sediment by Amax of Canada Ltd. and Environment Canada indicated that tailings deposition was confined to Alice Arm, and had not been detected beyond the sill which separates the arm from Observatory Inlet.

Amax of Canada Ltd. is proposing to start operation in 1981 and will be producing about twice the tonnage of ore per day than that of the previous operation. The present ore reserves are expected to last about 26 years and represents some 100 million tonnes in total. The tailings disposal system will consist of a pipeline from the mill which will be situated between the mouth of Lime Creek and Roundy Creek and extend to a depth of 50 metres below the surface of Alice Arm.

After undertaking several feasibility studies of on-land tailings disposal, Amax Canada Ltd. applied for special provisions under the Fisheries Act to discharge tailings directly in Alice Arm. Based upon available information from studies by Amax of Canada Ltd., the Federal departments of the Environment and Fisheries and Oceans, it was decided that marine disposal would be an acceptable environmental option over the long term, in view of the risks presented by a tailings dam, particularly after the mine had shut down. While disposal of tailings on land would not be impossible, it would be clearly a difficult proposition. Failure of a tailings dam could have greater environmental consequences (e.g., the destruction of fisheries and wildlife resources using the Kitsault/Illiance River estuary) than the impacts predicted for marine disposal in Alice Arm. Although it is not possible to predict the possibility of a major tailings dam failure, and it might never occur, the difficulties of maintaining a tailings pond forever in an earthquake zone under heavy rain and snowfall conditions, led the departments to recommend marine disposal of tailings under certain prescribed conditions. This, plus the fact that the area had previously been the site for marine tailings disposal (tailings which are now covered by natural sediments) led the departments to accept the application to discharge tailings directly into Alice Arm, under certain prescribed conditions set out in the Alice Arm Tailings Deposit Regulations.

Since March 1980, considerable controversy has developed between the Federal and Provincial governments which authorized the mine discharge permits and the Nishga Tribal Council and its supporters. The Nishga Council wanted a full public inquiry together with a revocation of the federal Alice Arms Tailings Deposit Regulations and a moratorium on construction of the marine facilities (Koch, 1981). The Council announced that it would launch a nationwide campaign to attempt to force a public inquiry. The Tribal Council and the Federal Member of Parliament for Skeena questioned the fact that the Federal Tailings Disposal Permit issued by Order-In-Council was the first and only exemption of its kind under the Fisheries Act (Fulton, 1981).

The situation was complicated by the fact that there were conflicting opinions by experts inside and outside the various levels of government on the interpretation of scientific data. In addition, support for the Nishga Council in its demands for a public inquiry had grown to include seven major church organizations, the British Columbia Federation of Labour, the United Fishermen's and Allied Workers' Union, and a large number of environmental and conservation groups.

Under the circumstances it was inevitable that comparisons would be made with the Island Copper Mine tailings discharges into Rupert Inlet, British Columbia where the tailings have spread over a much larger area than anticipated in the design phase (*see* Chapter 5). Attempts to compare the behaviour of tailings discharges into the two different bodies of water is a complex problem. There are several very significant differences between Rupert Inlet and Alice Arm. Alice Arm is more than twice as deep. While Alice Arm is not without currents, they do not compare with the strong

Iron ore tailings pumped into Wabush Lake, Iron Ore Company of Canada, Carol Lake mine, Labrador
John MacLatchy, Environment Canada

currents found at the junction between Quatsino Narrows and Rupert Inlet. Despite the major physiographic differences between the two receiving environments, and the more extensive baseline studies done at the new Amax site, opponents of the mine have continued to equate its effects on the marine environment with those of Island Copper.

On March 27, 1981 the Federal Minister of Fisheries and Oceans did agree to the establishment of an independent three-man scientific panel to review the information in which the government decision to allow tailings deposition in Alice Arm was based. The Minister assured the panel and the Nishga Council that he would reconsider his position should the panel's recommendation be negative. The Nishga Tribal Council announced that they would boycott the review panel's open discussions because it lacked the power to subpoena and cross-examine experts (McLaren, 1981).

After months of controversy, the panel released its report (Burling *et al.*, 1981) in July, 1981, revealing that all the substances of environmental concern in the Amax tailings occurred in concentrations less than those specified in the Alice Arm Tailings Deposit Regulations and the Canadian Drinking Water Objectives. In addition, the impact on commercial and/or food species is expected to be small, and will not significantly affect the fish harvest. The entire report has been set out in detail for public review.

The panel also recommended additional research and abatement programs including the following:

"Lead, zinc and possibly cadmium occur in the tailings solids at higher than local background levels. Because of this an abatement program for these substances is recommended. In the event that elevated levels of these or other substances of concern result in Alice Arm biota appropriate abatement programs should be mandatory.

"Extension of the Amax/Kitsault outfall from 50 to 100 meters depth is recommended as a means of limiting the distribution of suspended and deposited tailings.

"A variety of special studies are recommended including accelerated research on abatement techniques; tests of metal uptake from sediments by invertebrate animals; and various oceanographic, chemical and biological and engineering studies." (Burlington et al., 1981).

The Amax mine — Nishga Tribal Council issue is indicative of some of the real problems facing the mining industry in the 1980's and beyond. It is no longer possible to deal with straight forward economic and hardware decisions. Mining is now vulnerable to a wide range of social values, often varying from region to region and based on interpretations of information often misinterpreted, misquoted, and misunderstood. Issues concerning the quality of life can now attract and build up the support of a wide range of divergent social groups through today's means of instant communication. In this particular issue, the new mine found itself dealing with attempts to prevent the deterioration of fish resources, an unresolved native claims problem associated with jurisdictional responsibilities, and conflicting interpretation of expert advice.

Under the circumstances, it is becoming more and more evident that the role of political process is at the heart of the problem. Despite hard logical facts and their careful assessment, the political process has become increasingly significant. An open, administrative, and political process has to be seen to take place. Even now, logically the issue should disappear, but it is unlikely that it will do so completely. This is one of the rising problems facing regulators, developers, and politicians — how long must the process continue, one year or ten years, and at what cost?

Native claims coupled with fears of potential environmental and social impacts will continue to be a source of opposition and conflict over new and existing mines. For example, in 1980, the Cree nation of northern Alberta in action before the Federal Court of Canada are sueing for recognition of their aboriginal rights to over 51,780 square kilometres of oil sands and wilderness (Kennedy, 1980). Whereas, the Labrador Inuit Association and the Naskaapi—Montagnais Innu Association are against the proposed new Brinex Ltd. uranium mine in the Happy Valley—Goose Bay area. Much of the opposition stems from fear of the effects the mine might have on their present way of life (Globe and Mail, 1979). The predominantly non-native town council and Chamber of Commerce in Goose Bay support the mine, provided adequate environmental standards are maintained. The Province has responded by freezing any mine development for some time to come.

The banning or delaying of mineral exploration and development has become an increasingly prevalent occurrence in recent years. Much of it has been based on perceived fears of the potential effects that mines will have on adjacent land uses, water quality, and community way of life. This attitude is not restricted to native claims or the opposition of native groups to changes in their life style.

In the summer of 1978, exploration activities began in a promising uranium area stretching 180 kilometres from Ottawa to Kingston in eastern Ontario. Opposition to diamond drilling in a farming area centred on Newboyne, 100 kilometres southwest of Ottawa and in the tourist area around Sharbot Lake, resulted in the termination of exploration activities by the end of 1980. (Ottawa Journal, 1980; Globe and Mail, 1980). Many residents felt that there was risk of radiation poisoning to the groundwater supply from the diamond drilling. Opposition to the idea of a mine developing in the area was fueled by references to the poor record of environmental control and clean-up at previous mines. Concern was raised that no effective method has yet been devised to contain the potential pollution effects of tailings after abandonment and the long-term effects it may have on water supplies.

Similar fears and lack of faith in regulatory authorities were expressed during the ***Royal Commission of Inquiry into Uranium Mining in British Columbia*** (British Columbia, Province of, 1980). However, there are important consequences of the early termination of exploration activities. In the case of the seven-year moratorium on uranium exploration in British Columbia, the information-gathering process was terminated for both mineral and environmental data. This results in long-range planning of land use, environmental protection, and the allocation of resources continuing to be made with an inadequate data base. The Royal Commission published its findings in October, 1980, and the "Foreword" dealt with these long-term concerns in the following way:

"We think it possible that in the future the requirements for energy may be so pressing that all the known uranium in the Western World has to be mobilized if our essential freedoms are to be protected. If this were the case now, with presently available technology, it would be possible to develop uranium mines but at the cost of some long term environmental degradation. A degree of protection could be provided for the work force superior to what has been customary in previous uranium mining.

"We believe that the technology of tailings disposal is improving, and if adequate and generous research funding were provided, there are indications that in the next few years, uranium tailings, by extraction of radium-226 and thorium and by concentrating it, could be made environmentally

as harmless as are any other mine tailings. Furthermore, at the present time, if the resolution to do so existed, the work force could be so well protected in our opinion, that the additional risks of uranium mining compared to other types of mining would be minimal. It is very possible, if enough attention is given to these matters, that at some time in the future when the demand for uranium from British Columbia is pressing, these two major problems of uranium mining will have been mitigated. The point has been made to us by representatives of industry, governments, unions and members of the academic community that research and development to improve the safety of all aspects of uranium mining is of relatively recent origin. We anticipate the likelihood of advances in the future.

"We do not take a position that there is any ethical or moral basis, regardless of improvements in these matters which may well occur in the future, which would absolutely forbid the development of uranium mining.

"In the intervening period, provided that proper controls of such activity are structured and implemented, and provided that it is considered prudent to determine for the future what uranium resources may exist in the Province of British Columbia, we see no reason to prohibit uranium exploration from the point of view of environmental protection or protection of public health." (British Columbia, Province of, 1980).

Under the circumstances the Commission recommended that ***"provided that a licensing procedure for uranium exploration is instituted in British Columbia, the moratorium on uranium exploration should be lifted. We make this recommendation in the belief that, with proper control, the possible risks attendant on this activity would be outweighed by the benefits of the knowledge gained." (British Columbia, Province of, 1980).***

The key words were proper controls and licensing. But this will require a considerable change in public attitudes towards the mining industry and faith in regulating authorities at all levels of government if further conflicts are to be overcome. It will require a considerable improvement in the dissemination of information by both government and industry sectors in the exploration, extraction, and processing phases; mitigating procedures; and active demonstrations of "progress" being made to protect the environment and viability of neighbouring land uses.

CONFLICTS BETWEEN DEVELOPERS AND NON-DEVELOPERS

Much of today's conflict between those who want to develop the mineral resources of certain lands and those who urge conservation and protection of the same land resources is centred in the ***Yukon and Northwest Territories*** of Canada. The 3.8 million square kilometres of the Northwest Territories and Yukon are under the authority of the Territorial Lands Act (1952) administered by the Department of Indian Affairs and Northern Development (DIAND). In 1971, a managed-use component was added to the Act through the introduction of Territorial Land Use Regulations. In 1977, the Regulations were revised to apply to almost any type of activity that could create an environmental impact (Lucas and Peterson, 1978). However, a major exception to the implementation of these Regulations occurs in the Yukon where mining legislation takes precedence. Part of the managed-used concept implied in the Regulations was that there would be no moratorium on territorial lands pending the settlement of land claims. The general policy pursued was one of encouraging non-renewable resource development while ensuring that environmental impacts were kept to a minimum.

In recent years, there appears to have been a significant departure in the concept of managed or planned land use to one of preferential land use. This has been reflected in the growing exclusion of mining and oil companies from large tracts of land. They include, for example, the north shore of the Yukon Territory; the Bathurst Peninsula area of the District of MacKenzie; part of Somerset Island; and the Baker Lake area in the Keewatin. Much of the thrust against mining exploration and development has grown with the native peoples' opposition to the increased activity and potential effects they may have on wildlife resources and their traditional way of life, particularly on lands they have used and occupied for centuries.

The mining industry has opposed the introduction of what appears to be a form of planning which gives primacy to non-mining uses. Much of the mining industry's concerns are reflected in the report of the Northern Mineral Advisory Committee (Dep. Indian Affairs and Northern Development, 1979a). Some of the recommendations to the government affecting northern land-use options are listed:

"The Government of Canada will foster, promote and encourage prospecting, exploration and mining in the Yukon and Northwest Territories in recognition of the fundamental and major role of non-renewable resources in the economic and

social development in the North. The Committee supports the principle that economic development of the North must proceed with full recognition of the legitimate interests of Northern people and the protection of the Environment . . . .

"A preferred option with respect to the reservation of surface lands for any parties is that all mineral rights remain vested in the Crown. Although some mineral alienation may occur in the COPE settlement, the Committee does not regard this part of the agreement as an essential element in land settlements — there will be areas where economic development is prohibited or restricted. These lands should consist of only the minimum area required to achieve the objective and their selection should take into account their potential mineral value . . . .

"Access to mineral rights or to non-alienated areas should be maintained, notwithstanding any subsequent alienation of the surface rights. On all lands where development is not prohibited, access should be assured for prospecting, staking, exploring and developing mineral resources . . . .

"Land use Policy should endeavour to achieve and maintain a balance between economic development and environmental protection. The Committee recognizes that reasonable and positive efforts must be made by all parties to minimize disturbance of the natural environment . . . .

"Northern people will be encouraged by both government and industry to participate in Northern Canada's mining industry." (Dep. Indian Affairs and Northern Development, 1979a).

Criticism of the Adivisory Committee's report and recommendations came from Nunatsiaq MP Peter Ittinuar in the House of Commons in November, 1979. He pointed out that the committee ignored the broad implication of its mandate in favour of narrow mining interests, and that no discussions were held with native groups or other special interest groups. Mr. Ittinuar's uneasy conclusion about mineral development in the north:

". . .is that policy is being formed by industry and government behind closed doors. Such approaches to development decision-making can only heighten suspicion and mistrust; and that is the process going on now." (House of Common Debates, 1979).

He questioned the implication that land set aside for conservation and environmental protection should be

Tundra Gold Mines Ltd., Matthews Lake, Northwest Territories, abandoned in 1968
John Reid, Environment Canada

located in those areas where no minerals had been discovered rather than where environmentally sensitive features or wildlife populations need to be protected. Similar doubts were raised by the Canadian Arctic Resources Committee (1981) which pointed out that native peoples, local government officials, and environmental organizations were not consulted by the committee. Mr. Ittinuar emphasized that the Inuit were not opposed to development per se, but did oppose rapid, untimely development that endangered their land, people, and way of life. The general feeling of the Inuit towards the current policy and procedures for mineral development were summarized in the words of Elijah Takkiapike quoted before the House in the same speech.

"We very much dislike white people taking our land for granted. It seems they feel they can destroy our land any time they feel like it without even asking for permission. We want to have freedom of conservation with the animals. They steal the raw materials without even consulting us or giving the Inuit a percentage of what they are taking. We need to get power to control the land." (House of Commons Debates, 1979).

The mining industry's demands for complete access to the land and less-restrictive environmental controls were criticized by the Canadian Arctic Resources Committee (CARC) and others on the grounds that past experience of mining activities in the North showed that all prospecting and development must be regulated (CARC, 1981). As yet, no mine has been subject to a formal and comprehensive environmental-social impact assessment north of 60° (Keith *et al.*, 1981). The general approach to mine development has been piecemeal.

Native, environmental, and conservation groups have considerable skepticism of the existing protection measures considering the problems experienced at Cypress Anvil, Pine Point, and Cassiar Asbestos (Macpherson, 1978*a* and 1978*b*; Atkin-Baker, 1979; and Sallot, 1979). Much of the opposition is related to the effects of tailings effluent discharges on fish and game populations. Many of the problems of verification of damage stem from the fact that no environmental studies were required prior to the development of the existing mines. Consequently baseline data was unavailable to verify whether or not changes in water chemistry are mainly attributable to the mines. Doubt about the effectiveness of remedial measures by mining companies and government enforcement is increased when evidence of non-compliance with water license regulations by some mines continues (Atkin-Baker, 1979). One of the difficulties in maintaining water quality on mining projects is the use of authorization permits rather than licences issued by the Water Board (under the Northern Inland Waters Act). Much of this is a reflection of the *ad hoc* approach to land use in the north, as MacLeod (1977) points out:

"The effect of the use of authorization as a project escalates through exploration to actual production may be to prejudice the environment through "creeping development". . . .The less stringent requirements of authorizations may themselves prejudice the quality of the environment to such an extent that when a water licence is finally considered, the original environmental values the act was designed to protect may be partially lost."

Existing land use and environmental regulations were imposed to overcome many of these past problems, but it is evident that they have failed and will continue to do so unless a comprehensive land use plan or resource management policy for the northern territories is developed (Naysmith, 1973, 1975; McTaggart-Cowan, 1976; Lucas and Peterson, 1978; Rees, 1978; and Keith *et al.*, 1981).

Much of the problem in developing such a plan has been the lack of adequate information on the capability and limitations of the land, as well as type, amount, and distribution of the North's non-renewable resources. Any attempt to introduce a land use plan will inevitably be affected by negotiations on native land claims settlements. Although alignments of conservation, environment and native groups in opposition to major resource developments have occurred on a regular basis, they do break down when the designation of land for conservation and recreation areas arises. Proposals for the establishment of a wilderness park in the northern Yukon led to the withdrawal of 38,850 square kilometres of land in July, 1978 (Redpath, 1979), but it forms an integral part of the land claims agreement in principle between the Committee for Original Peoples Entitlement (COPE) and the Federal government. It has become more of an issue with the heightened interest in potential mineral and energy resources of the region.

The situation in the North has become exceedingly complex given the number of independent demands for a wide range of recreation- and conservation-oriented land uses demanded, for example, archaeological, historical and IBP sites, wilderness, reserves, wildlife sanctuaries, and national parks. The lack of progress in native land claims has effectively frozen the process of the federal land allocation. In fact, it has put

extreme strain on all resource and conservation proposals.

Demands for a comprehensive land-use plan in the northern territories are further complicated by the problems associated with the split in Federal and Territorial jurisdictions. Much of this is reflected in the fact that the evolution of responsibility between the two levels is still in progress, and thus subject to overlaps and conflicts in administration. This is further complicated by the split in jurisdiction between various federal departments for management and protection of land and water resources, for example, between the departments of Fisheries and Oceans, Environment, and Indian Affairs and Northern Development. The Department of Indian Affairs and Northern Development also has the improbable task of attempting to meet the demands of three client groups — native peoples, resource developers, and those urging protection, conservation, and management.

Nowhere is this more evident than in the issues associated with the rapid expansion of ***placer mining in the Yukon***. Placer-mining operations of today can strip whole streams in a very short time, destroying vegetation in the valley bottoms; altering stream channels, adjacent banks, and flood plains; and releasing vast amount of suspended sediments into their respective drainage networks. The environmental damage by placer operations on streams designated as traditional mining areas has made them unsuitable for other land or water uses. Because there is very little experience in reclaiming abandoned placer operations or knowledge of the ability of former disturbances to recuperate unaided, many of these areas may be alienated from alternate use for some time to come, or may even be beyond recovery. Because of the vast number of claims on each stream, it is very difficult to regulate or assign repsonsibility for either individual or cumulative effects on the downstream environment. The resulting poor water quality is having an effect on existing and proposed federal and territorial land uses such as parks and campgrounds, wilderness areas, wildlife reserves, tourist operations, etc. Opposition from native groups stems from the deleterious effect that these operations have on traditional hunting, fishing, and trapping areas. Regulation and environmental control problems arise from the fact that the Territorial Lands Act and pursuant regulations do not apply to land claimed for placer mining. This precludes any regulating control over methods used by placer miners in exploration, production, and abandonment. Miners have consistently opposed any attempts to have the Territorial Land Use Regulations apply on mining lands. However, conflicts and administrative problems arise in the management of water resources. The Northern Inland Waters Act (NIWA) does not provide an effective mechanism for control of water use in relation to placer mining due to the large number of operators, seasonal nature, and frequent movement of operations. Under the NIWA the Yukon Territorial Water Board was established to licence all water-use operations. However, the dramatic increase in the number of operations in the past few years has resulted in authorizations to use water without a licence, but subject to terms and conditions determined by the Board on the advice of the Department of Environment officials. Under the NIWA terms and conditions, operations must conform to regulations passed under sections 31 and 33 of the Fisheries Act relating to habitat and the deposition of deleterious substances. Since most placer operations have adverse effects on fish habitats, there is a considerable problem in managing renewable and non-renewable resource conflicts. Indirectly the Water Board has found itself in the position of allocating land and water resources which is beyond the mandate of its authority. As the traditional streams associated with placer mining have been fully staked, pressure has been mounting to accommodate demand in new, as yet undisturbed, areas. Under the Yukon Placer Mining Act as it now stands, any person 18 years of age and over can locate, prospect, and mine for gold upon any lands in the Territory. Thus, the Klondike Gold Placer Mining Association is opposed to strict enforcement of Federal environmental regulations particularly those under the Fisheries Act. Many of their complaints are aimed at Federal fisheries' requirements for culverts and causeways on streams, and settling ponds and diversion channels to allow fish to move up and down streams unaffected by disturbances and excessive sediment. Since native land claims in the Yukon have not yet been decided, increased placer mining in new, as yet unaffected, areas is likely to heighten conflicts with native interests. It is likely that many opponents to placer mining will want to introduce not only compulsory environmental impact assessments as part of licence or authorization approvals, but also better monitoring and management of placer mining activities, reclamation of worked out areas, and trade-offs to protect particularly sensitive areas (Keith *et al.*, 1981).

North of 60°, until the confrontations over demands for self-government and native claims are settled, jurisdictional overlaps resolved, and an resource management plan developed, conflicts between mining and other land uses are likely to continue. These problems have raised three significant issues, all seriously affecting the future development of the north, namely:

Placer mining sluice box in operation, Thunder Gulch, Yukon Territory
Jim Scott, Environment Canada

(i) The allocation of land resources between renewable and non-renewable uses;

(ii) Resource and environmental regulation entanglements, leading to complex and costly delays in allocation and approval; and

(iii) The preservation and enhancement of the environment arising from demands for exclusive use or restricted access by many different groups.

The first indication of a response to these rising issues has been the recent announcement (July 31, 1981) by the Federal government of a new "Northern Land Use Planning Policy' (Dep. Indian Affairs and Northern Development, 1981). A formal land use planning system is to be established to improve the management of land-resource users in the Yukon and Northwest territories. Comprehensive land use planning is to be conducted through Federal land use planning commissions in each territory. Each planning commission consists of a land use co-ordinating committee which interprets policy, sets local objectives, and directs operational planning. It will include native, Federal, and territorial representation. Actual planning tasks will be conducted by a supporting planning secretariat. Both commissions report to the Minister.

Policy direction, objectives and priorities will be set by the "Northern Land Use Policy Committee' chaired by the Department of Indian Affairs and Northern Development and composed of representatives from Federal and territorial departments having northern land- and resource-related interests. The committee will be supported by the Land Use Planning Branch. The forum for public input is to be centred on the establishment of planning area review panels, to work on individual planning projects. The composition of the panels will be drawn from local residents, local government, and industry.

The proposed planning process is sequential, consisting of five basic steps:

"1. Plan initiation — terms of reference are developed within the context of the policy framework for approval by the Minister.

2. Resource inventory and analysis — baseline data is collected and analyzed to meet specific planning objectives.

3. Plan preparation — with Minister's approval a formal land use plan is selected from a number of alternatives. The plan will identify allowable land and resource uses and regulations for their management.

4. Plan implementation — once approved, all affected and participating agencies shall adhere to the provisions of the plan.

5. Monitoring and review — plans developed under a given set of circumstances will be amenable to change. Plans will be subject to revision as circumstances change." (Dep. Indian Affairs and Northern Development, 1981).

In terms of application, the government has identified the northern Yukon/Mackenzie Delta/Beaufort Sea; Lancaster Sound; MacMillan Pass; and the area south of Great Slave Lake for immediate, priority attention.

The implementation of the policy and the establishment of the organizational structures are still in their infancy. Therefore, it will be some time before any assessment can be made of its potential contribution to relieving resource conflicts in the North.

CONSTRAINTS TO FUTURE MINE DEVELOPMENT

Canada will continue to be faced with a growing number of environmental and resource-use conflicts related to the mining industry. The increased demand for mineral and energy resources to support Canada's economic development has been, and will continue to be, paralleled by a growing global demand for Canada's renewable and non-renewable resources. These demands will increase in the long term to create considerable added pressure on the land allocation process. Resource, consuming countries will look increasingly to Canada for raw materials, particularly food, forest products, energy, minerals, and, in the case of the United States, water. Of immediate concern will be the development of energy resources — oil, gas, coal, and uranium — many of which are found in ecologically sensitive areas or on prime agricultural lands. Growing global demands for food will put added pressure on the need to preserve Canada's agricultural land resource. This will only heighten already growing concerns over our ability to absorb losses of agricultural lands to other users. Water quality, and the balancing of its supply with demand are likely to become prominent issues in some regions. In addition, it can be expected that the continued rise in foreign travel costs will cause more and more Canadians to spend their leisure time in Canada, thus increasing the demand to set aside more land resources for recreation- and tourist-related activities. Furthermore, political, economic, and sociological considerations will continue to compound the problems associated with the land allocation pro-

cess whenever a given parcel of land possesses economically mineable mineral or energy-related resources. With these and other unresolved issues such as native claims, it is not surprising that further acquisition of land by the mining industry will continue to meet with varying degrees of resistance.

Table 55 has been compiled in order to provide some indication of the potential range of land use and environmental constraints that future mining developments are likely to encounter in Canada. In essence, the table is a subjective evaluation of the probability of a negative response to future mining developments from the various land-use sectors and interest groups based on information presented in this report. The assessment is according to the anticipated severity of competition or opposition to mining within each of the land-resource zones. It must be pointed out, however, that many potential constraints implied in the table could disappear overnight should solutions to long-standing problems be resolved, for example native land claims, jurisdictional rights, and the establishment of strategies for land use planning and resource management. Much of the assessment takes into account the importance and magnitude of past impacts and the role they played in fostering land use conflict. This includes the extent of mining operations, existing environmental problems, and sensitivity of the receiving environment. Many potential conflict situations in the future are likely to be less controversial or even eliminated at new mine sites, due to the effects of a decade of stricter environmental and land use regulations governing mining and the introduction of better technology for pollution control.

In order to maintain the anticipated level of output projected to the year 2000 for mineral and energy resources, considerable land resources will be required, many in areas as yet unaffected by mining. The additional requirements for "infrastructure" to support these new developments will increase the harmful effects on the land. This is particularly evident in situations requiring major new transportation facilities. It is likely that many of these future mine developments will not proceed without the settlement of outstanding native claims and the enforcement of adequate environmental protection measures. Map 25 identifies those land-resource zones where native rights are likely to be a significant constraint to future mine development in the next decade. The areas in question closely parallel outstanding native claims (*see* Map 23). Indeed, the question of deteriorating native life styles has increased the potential opposition to new mines in the vicinity of already existing Indian Reserves. Localized opposition from native groups will

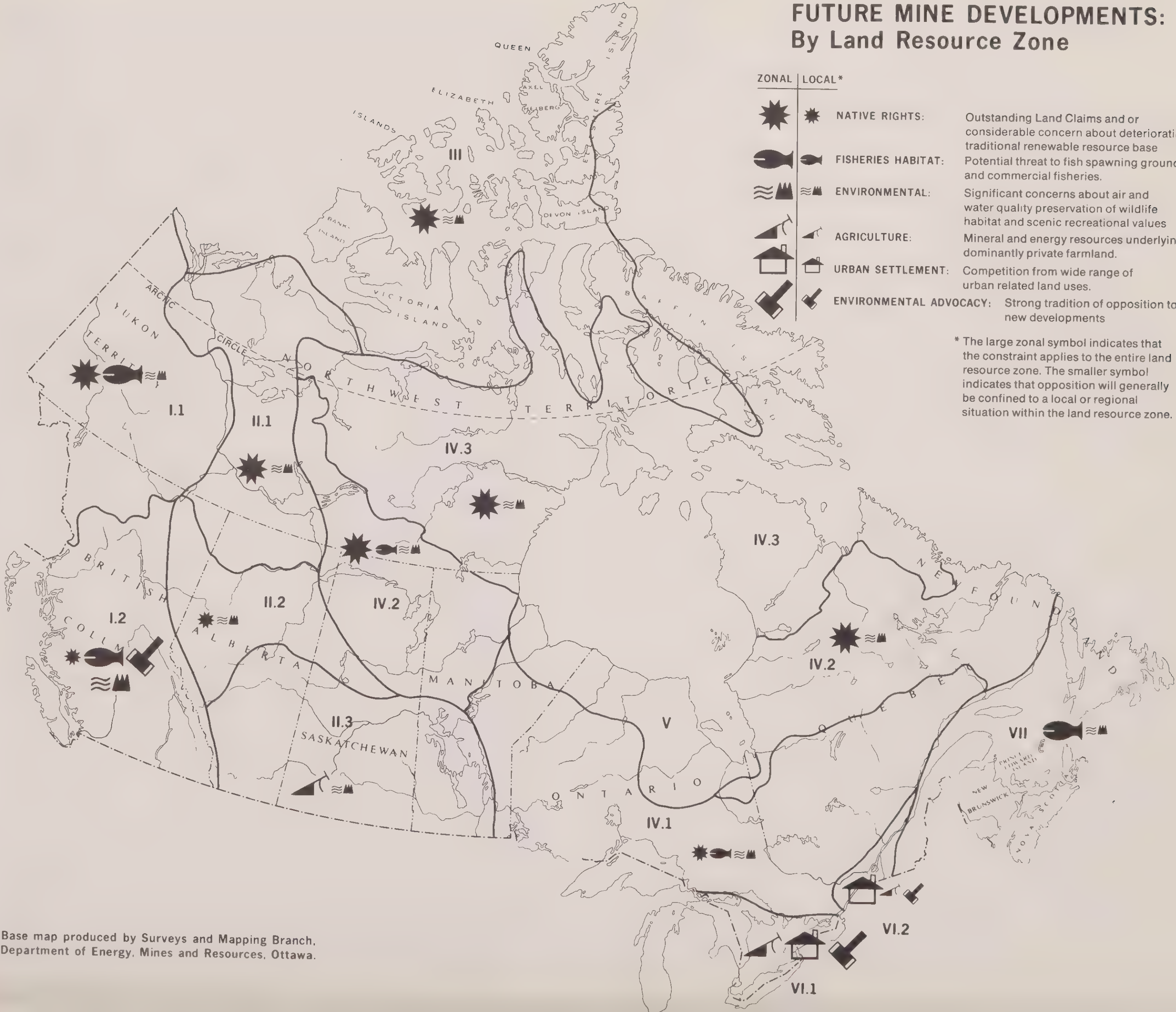
Placer mining, Thunder Gulch, Yukon Territory
Jim Scott, Environment Canada

TABLE 55. POTENTIAL LAND USE AND ENVIRONMENTAL CONSTRAINTS TO FUTURE MINING DEVELOPMENTS IN CANADA: BY LAND RESOURCE ZONE

Land Resource Zone	Mining Sector	Probability of Future Mine Development	Agriculture	Forestry	Urban Growth	Wildlife/ Wilderness Preservation	Tourism and Outdoor Recreation	Fisheries	Native Land Claims	Water Quality
I.1 Northern Cordilleran	Metals (inc. Placer)	H	-	-	-	H	H	H	H	H
	Coal	M	-	-	-	H	H	M	H	M
I.2 Southern Cordilleran	Metals	H	L-M	L-M	L	H	H	H	H	H
	Coal	H	L	L-M	L	H	H	H	H	M
	Industrial Minerals	M	L	L-M	L	H	H	H	H	L
	Structural Materials	H	H	L-M	L-M	H	M	L-H	M	L
II.1 Northern Interior Plains	Metals	L	-	-	-		M-H	L	M-H	L
II.2 Central Interior (Peace, Athabasca)	Oil Sands	H	-	L	L	M-H	M	M	M	M-H
	Coal	L-M	L	M	L	M-H	H-M	L	L-M	L-M
II.3 Southern Interior Plains (Prairies)	Coal	H	H	-	-	M	-	-	-	H
	Industrial Minerals	H	H	-	-	-	-	M	-	M-H
	Structural Materials	M	M-H	-	L-M	-	-	-	-	L
III.1 Arctic Archipelago	Metals	M	-	-	-	H	-	L	H	L-M
IV.1 Southern Boreal Shield	Metals (incl. Uranium)	H	L	M	L	H	H	H	L-M	H
	Industrial Minerals	M-H	-	M	L	M	M-H	H	L	-
IV.2 Central Subarctic Shield										
Quebec-Labrador	Metals (Iron)	H	-	-	-	L	L	M-H	M-H	M-H
Manitoba-Saskatchewan	Metals (incl. Uranium)	H	-	-	-	H	H	H	H	H
IV.3 Arctic Shield	Metals (incl. Uranium)	M-H	-	-	-	H	L	M-H	H	M-H
V.1 Hudson Bay Lowland	Peat	L-M	-	-	-	M-H	-	L-M	L	L
VI.1 Lower Great Lakes	Industrial Minerals	M	H	-	H	L	H	L	-	L
	Structural Materials	H	H	-	H	L	H	L	-	L
VI.2 Central St. Lawrence Lowlands	Industrial Minerals	H	H	-	M	L	H	L	-	L
	Structural Materials	H	H	-	H	L	H	L	-	L
VII. Appalachian	Metal	H	L	M	L	M-H	H	H	L	H
	Coal	H	L	M	L	M-H	H	M	L	M
	Industrial Minerals	H	L-M	L-M	M-H	M-H	H	M	L	L
	Structural Materials	H	M	L	M	M	H	L	L	L

H = high; M = medium; L = low.

MAP 25. SIGNIFICANT CONSTRAINTS TO FUTURE MINE DEVELOPMENTS: By Land Resource Zone



ZONAL	LOCAL*		
		NATIVE RIGHTS:	Outstanding Land Claims and or considerable concern about deteriorating traditional renewable resource base
		FISHERIES HABITAT:	Potential threat to fish spawning grounds and commercial fisheries.
		ENVIRONMENTAL:	Significant concerns about air and water quality preservation of wildlife habitat and scenic recreational values
		AGRICULTURE:	Mineral and energy resources underlying dominantly private farmland.
		URBAN SETTLEMENT:	Competition from wide range of urban related land uses.
		ENVIRONMENTAL ADVOCACY:	Strong tradition of opposition to new developments

* The large zonal symbol indicates that the constraint applies to the entire land resource zone. The smaller symbol indicates that opposition will generally be confined to a local or regional situation within the land resource zone.

Base map produced by Surveys and Mapping Branch, Department of Energy, Mines and Resources, Ottawa.

most likely arise in the Southern Cordillera, Central Interior Plains, and the Southern Boreal Shield zones.

Because the traditional native life style is based on hunting, trapping, and fishing in most forested regions, it is not often possible to separate the concerns of other land-use sectors — fisheries, tourism and outdoor recreation, wildlife habitat, wilderness preservation, and water use — from native land claims issues.

Because fisheries (commercial and recreational), tourism, recreation, and wildlife/wilderness preservation uses are rarely compatible with mining, they will always be among the strongest opponents to mine developments over the widest possible range of environmental conditions. Under the circumstances there will always be some localized opposition to mines based on a wide range of environmental concerns including water quality, fish and wildlife habitat, aesthetic values, health, and safety. The most widespread example of this type of opposition in recent years has been associated with the uranium industry. With the exception of the Lower Great Lakes and St. Lawrence Lowlands, localized opposition will continue to materialize throughout the remaining land-resource zones of Canada. Mining in the Southern Cordillera will continue to experience the most intense opposition for the above-mentioned reasons.

Although forestry is an extensive user of land, it does not normally have any compatibility problems with mining. Both activities tend to develop in remote areas where there are often other strong interests in recreation, tourism, and the preservation of wildlife habitat. Competition or conflicts over the use of land between mining and forestry are generally rare. Most differences arise out of responsibility for disturbances and subsequent damage when representatives of both resource sectors are operating in the same area.

Formidable, direct competition for land resources will always be present in the case of land under agricultural use. Most of this is in private ownership and not owned by the Crown. This will have a particularly strong impact on the future expansion of strip coal mining in the southern Interior Plains and open-pit sand and gravel operations in the Lower Great Lakes resource zone. More-localized opposition from agricultural land users to mining can be expected in the central Interior Plains (coal, and oil sands) and the central St. Lawrence Lowlands (sand, gravel, and crushed stone).

Direct competition for the same parcel of land with mining is not a normal occurrence except in the case of native claims, agricultural land, and related land uses. In Canada, the central St. Lawrence Lowlands and Lower Great Lakes are the only land-resource zones where the density of urban settlement is sufficient to arouse continued opposition to aggregate mining operations. The competition for land in these zones is enhanced by claims of the agricultural resource sector.

The potential threat of mining activities to fish habitats and subsequently the livelihood of commercial and sport fisheries will continue to arouse opposition to new mine developments throughout the Cordilleran and Appalachian Resource Zones. Localized cases of opposition are likely to arise along the entire southern rim of the Canadian Shield.

The growth in the number of environmental and conservation pressure groups coupled with other concerned organizations has led to the establishment of a strong tradition of environmental advocacy in opposing mining in some resource zones of Canada. The two most prominent areas are the Southern Cordillera and Lower Great Lakes, and, to a lesser extent, the St. Lawrence Lowlands. In the case of the latter two, opposition is largely directed toward the aggregate industry and the establishment of nuclear-related establishments.

The Northern and Southern Cordillera zones are likely to have the widest range of constraints to future mine developments. The combination of native rights and associated environmental constraints is likely to be the most widely felt by the mining industry. This may be compounded by jurisdictional and resource-management problems, particularly on those lands under Federal authority.

Coal preparation plant, Fording Coal Ltd., Elkford, British Columbia
I.B. Marshall, Environment Canada

Abandoned mine, Maniwaki, Quebec
NFB — Phototheque — ONF, Gilles Benoit

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APPENDIX I. — **MINING OPERATIONS THAT AFFECT THE LAND SURFACE**

PRE-PRODUCTION STAGE			OPERATIONS THAT AFFECT THE LAND SURFACE																											
PHASES	ACTIVITIES		Equipment Operation	Vegetation Removal	Topsoil Removal	Overburden Removal	Topsoil Storage	Overburden Disposal-Storage	Site Clearing	Grading	Cut and Fill	Blasting and Drilling	Excavation	Backfilling	Material Capping	Seedbed Preparation	Roadbed Preparation/Surfacing	Drainage Alteration	Stream Crossing/Bridging	Dams and Impoundments	Dewatering	Building Construction	Mineral Extraction	Mineral Storage	Loading	Hauling	Erosion Control	Planting/Seeding	Fertilization	Operation and Maintenance
EXPLORATION	SURVEYING	GROUND:																												
		Geophysical	X	X																										
		Geochemical	X	X																										
		RECLAMATION: Limited	X													X											X	X	X	
	DRILLING TESTS	Access Road	X	X					X	X																	X			
		Construction/Drill Pad	X	X	X				X	X																				
		Construction of Sump	X	X	X			X					X																	
		Operation of Drill	X																											
		RECLAMATION	X											X	X	X											X	X	X	
	MINING TESTS	Access/Haul Road	X	X					X	X							X									X				
		Trench, Adit or Pit	X	X	X	X	X	X	X			X														X				
		Bulk Sampling	X																				X	X						X
		RECLAMATION	X											X	X	X											X	X	X	

APPENDIX I. — **MINING OPERATIONS THAT AFFECT THE LAND SURFACE** *Cont'd*

PRE-PRODUCTION STAGE			OPERATIONS THAT AFFECT THE LAND SURFACE																											
PHASES	ACTIVITIES		Equipment Operation	Vegetation Removal	Topsoil Removal	Overburden Removal	Topsoil Storage	Overburden Disposal-Storage	Site Clearing	Grading	Cut and Fill	Blasting and Drilling	Excavation	Backfilling	Material Capping	Seedbed Preparation	Roadbed Preparation/Surfacing	Drainage Alteration	Stream Crossing/Bridging	Dams and Impoundments	Dewatering	Building Construction	Mineral Extraction	Mineral Storage	Loading	Hauling	Erosion Control	Planting/Seeding	Fertilization	Operation and Maintenance
DEVELOPMENT	MINERAL EXTRACTION SITE	Underground	X	X	X				X	X		X	X								X				X	X				
		Surface	X	X	X	X	X	X	X			X	X					X							X	X				
Construction of Facilities	TRANSPORTATION FACILITIES	Access Road	X	X					X		X	X					X	X	X						X	X	X			
		Haul Roads	X	X					X		X	X					X	X	X						X	X	X			
		Railroad	X	X					X		X	X					X	X	X						X	X	X			
	SUPPORT FACILITIES AND UTILITIES	Electrical:																												
		Transmission Lines	X	X					X			X						X				X				X	X			
		Substations	X	X					X			X						X				X				X				
		Water Supply:																												
		Drilling Wells	X	X					X																					
		Pump Station	X	X					X													X				X				
		Pipeline	X	X					X	X			X	X				X	X							X				
		Building, Plant	X	X					X				X					X				X			X	X				
		Parking Lot	X	X					X	X							X	X							X	X				
	BENEFICIATION FACILITIES	Ore Storage	X	X					X				X					X				X					X			
		Mill	X	X					X				X					X				X								
		Loading	X	X					X				X									X								
	WASTE DISPOSAL FACILITIES	Waste Dumps	X	X	X		X		X	X										X							X			
		Tailings/Sediment Ponds	X	X	X	X	X	X	X				X							X					X	X				
		Sewage Treatment	X	X					X	X			X	X								X								
		Runoff Controls	X	X									X	X						X							X			
		Polishing Ponds	X	X	X	X	X	X	X				X												X	X				

APPENDIX I. — **MINING OPERATIONS THAT AFFECT THE LAND SURFACE** *Cont'd*

PRODUCTION STAGE			OPERATIONS THAT AFFECT THE LAND SURFACE																											
PHASES	ACTIVITIES		Equipment Operation	Vegetation Removal	Topsoil Removal	Overburden Removal	Topsoil Storage	Overburden Disposal-Storage	Site Clearing	Grading	Cut and Fill	Blasting and Drilling	Excavation	Backfilling	Material Capping	Seedbed Preparation	Roadbed Preparation/Surfacing	Drainage Alteration	Stream Crossing/Bridging	Dams and Impoundments	Dewatering	Building Construction	Mineral Extraction	Mineral Storage	Loading	Hauling	Erosion Control	Planting/Seeding	Fertilization	Operation and Maintenance
EXTRACTION	MINING	Underground	X									X		X							X		X	X	X	X				X
		Surface	X	X	X	X	X	X			X	X		X				X			X		X	X	X	X	X			X
	WASTE DISPOSAL	Rock Dump	X																						X	X	X			X
BENEFICIATION	MILLING	Cominuation: Crushing-sizing Grinding-classification																												X
		Concentration: Flotation, Gravity Separation, Electric or Magnetic																												X
	TRANSPORT	Road, Rail, Conveyor	X																						X	X				X
	WASTE DISPOSAL	Tailings Pond																									X			X
		Sewage																												X
		Run-off Controls																									X			X
		Polishing Ponds																									X			X
		Dust Collectors																												X
FURTHER PROCESSING	SMELTING, REFINING	Pyrometallurgical																												
		Hydrometallurgical																												X
		Electrometallurgical																												
		Gas Scrubbers																												X
	TRANSPORT	Road, Conveyor	X																						X	X				X
	WASTE DISPOSAL	Slag Dump	X																						X	X	X			X
		Residue Dump	X																						X	X	X			X
		Sulphur Storage/Dumps	X																						X	X	X			X

APPENDIX I. — **MINING OPERATIONS THAT AFFECT THE LAND SURFACE** *Cont'd*

POST-PRODUCTION STAGE — OPERATIONS THAT AFFECT THE LAND SURFACE

PHASES		ACTIVITIES	Equipment Operation	Vegetation Removal	Topsoil Removal	Overburden Removal	Topsoil Storage	Overburden Disposal-Storage	Site Clearing	Grading	Cut and Fill	Blasting and Drilling	Excavation	Backfilling	Material Capping	Seedbed Preparation	Roadbed Preparation/Surfacing	Drainage Alteration	Stream Crossing/Bridging	Dams and Impoundments	Dewatering	Building Construction	Mineral Extraction	Mineral Storage	Loading	Hauling	Erosion Control	Planting/Seeding	Fertilization	Operation and Maintenance
RECLAMATION		Ground Preparation	X							X				X	X						X				X	X				
		Surface Treatment and Amendments	X																										X	
		Revegetation	X													X												X		X
		Drainage	X								X										X						X			
		Irrigation	X																											X
ABANDONMENT		Dispose of, remove or abandon all equipment, and facilities	X					X						X	X										X	X	X			X
TEMPORARY CLOSURE	FACILITIES	Extraction Site																			X						X			X
		Milling																												X
		Refining, Smelting																												X
		Transport																												X
		Waste Disposal																									X			X

APPENDIX II.

AVERAGE AREA OCCUPIED BY MINE WASTES AND OPEN PITS AT CANADIAN MINE SITES

A: CANMET, Mine, Waste Inventory by Satellite Imagery

	OPEN PIT	OVERBURDEN	SLURRY POND	TAILINGS	WASTE ROCK	SLAG
			(hectares)			
Total Area	1,434	21,996	2,777	17,478	7,157	283
No. of Mines Involved	39	150	51	250	108	4
Average area per mine	37	147	54	70	66	71

B: Environment Canada Questionnaire on Metal Mining

		OPEN PIT	TAILINGS	WASTE ROCK
			(hectares)	
Average Area per mine	Underground		83	5.3
	Open Pit	51	219	75
No. of mines Involved	Underground	50	38	22
	Open Pit	52	38	47

Sources: Environment Canada, 1972; Murray, 1977b.

APPENDIX III.

NUMBER OF PITS AND QUARRIES IN EASTERN CANADA WITHIN 8 KM OF POPULATED CENTRES

AREA	SAND AND GRAVEL PITS Distance from Populated Centres			QUARRIES Distance from Populated Centres			TOTAL: PITS AND QUARRIES Distance from Populated Centres			
	0.16 km	0.16-4.8 km	4.8-8.5 km	0.16 km	0.16-4.8 km	4.8-8.5 km	0.16 km	0.16-4.8 km	4.8-8.5 km	0-8.5 km
Northern Ontario	2	122	53	-	1	2	2	123	55	180
Western Ontario	50	386	109	4	19	2	54	405	111	570
Central Ontario	53	311	238	17	39	15	70	350	253	673
East Ontario/ Ottawa Valley	47	382	133	15	56	7	62	438	140	640
Northwest Quebec	1	34	23	-	-	-	1	34	23	58
Quebec - St. Lawrence Valley/Eastern Townships	44	289	215	12	31	11	56	320	226	602
Quebec - Lower St. Lawrence	3	71	29	-	-	-	3	71	29	103
New Brunswick	11	79	33	1	12	1	12	91	34	137
Nova Scotia	9	46	271	-	15	3	9	61	274	344
P.E.I.	3	31	4	-	-	-	3	31	4	38
Newfoundland	5	48	10	3	6	1	8	54	11	73
TOTAL:	228	1,799	1,118	52	179	42	280	1,978	1,160	3,418

Source: Environment Canada, 1977.

APPENDIX IV

RECLAMATION REQUIREMENTS

BRITISH COLUMBIA

General

(1) The mining company shall submit to the Senior Reclamation Inspector a plan of total reclamation prior to shut down.

(2) All buildings, machinery, mobile equipment shall be removed. All scrap material shall be disposed of in a manner mutually acceptable to the Ministry of Energy, Mines and Petroleum Resources and the mine operator.

(3) Concrete foundations and slabs may be left intact and covered by overburden and revegetated where practical.

(4) All provisions of either the Mines Regulation Act or Coal Mines Regulation Act shall be complied with to the satisfaction of the District Inspector or Resident Engineer.

Tailings ponds

(1) A plan shall be submitted showing the proposed drainage controls for the tailings pond and surrounding drainage area.

(2) Where necessary a permanent spillway is required on or adjacent to the tailings dam to provide for excessive runoff water. Details and design shall be submitted to the Chief Inspector of the Ministry of Energy, Mines and Petroleum Resources and the District Inspector for approval.

(3) Where practical the tailings pond shall be revegetated to a condition approved by the Reclamation Section of the Ministry of Energy, Mines and Petroleum Resources. If vegetation is to be established, it shall be done to a point where no maintenance of the vegetation is required. A minimum of three years experience is necessary to determine the quality of vegetation.

(4) Land use of the disturbed areas following mine abandonment shall be mutually agreed upon by the Ministry and the mine operator and shall take into consideration the use of the land prior to mining and the capability of the disturbed soil and/or mine waste to sustain the pre-mining land use.

Waste Dumps

(1) Where possible waste dumps should be sloped to an angle where vegetation can be maintained. If overburden is available, flat areas of the dumps shall be covered to a depth of three to six inches of overburden or top soil.

(2) All flat areas on the dumps shall be revegetated and vegetation shall be established to a point where no maintenance is required. A minimum of three years experience is necessary to determine the quality of vegetation.

(3) A plan of the drainage area surrounding the dumps shall be submitted to the Senior Reclamation Inspector. Where possible all drainage should be directed away from the dumps.

(4) Ultimate land use of the disturbed dump area shall be specified.

Pit Area

(1) Pits shall be backfilled whenever possible.

(2) A plan shall be submitted to the Senior Reclamation Inspector showing how the pit area shall be left after completion of mining.

(3) Where the pit area is going to be designated as a lake, a report shall be submitted to the Senior Reclamation Inspector outlining source of water, drainage area, maximum level of water, water quality, access to lake, plans for stocking of the lake.

(4) Where the pit floor will be free from water, where possible overburden shall be used to provide sufficient cover to establish vegetation.

(5) Pit walls shall be left in a safe manner to the satisfaction of the District Inspector of Mines.

ALBERTA

General

1. (1) In these Guidelines,

   (a) "Act" means The Land Surface Conservation and Reclamation Act;

   (b) "Approving Authority" includes the Land Conservation and Reclamation Council;

   (c) "Land Conservation Regulations" means Alberta Regulation 125/74 as amended from time to time and any regulations made in substitution therefore;

   (d) "Regulated Surface Operation Regulations" means any regulation designating any operation or activity named in Section 23 (1) of the Act to be a regulated surface operation pursuant to that section.

(2) Any expression that is defined in the Act, the Land Conservation Regulations, any Regulated Surface Operation Regulations, and any applicable Exploration Approval or Development and Reclamation Approval has the same meaning herein.

2. Disturbed lands shall be reclaimed to the condition and to achieve the post-disturbance land use that is prescribed

   (a) in the Development and Reclamation Approval issued in accordance with the applicable Regulated Surface Operation Regulations, or

(b) in the absence of an Approval, or other specified conditions, by the Council following consultation with the owner or operator, or both of them, as the case may require, or

(c) in the contractual agreement, lease or license of occupation agreed to between the owner (public and private lands) and the operator.

Drainage and Erosion Control

1. Water from catchment areas adjacent to the lands to be disturbed shall not be routed through the lands unless the operator takes precautions that in the opinion of the Approving Authority are adequate to prevent siltation and erosion of the lands to be disturbed.

2. Streamflows in and through natural drainage systems located on the lands to be disturbed shall be maintained by the operator through the installation of culverts or bridges, or the construction of interceptor or drainage ditches or other drainage systems that in the opinion of the Approving Authority are adequate to accomodate seasonal streamflows.

3. All interceptor or drainage ditches constructed by the operator shall have outlets consisting of natural drainage ways, vegetative areas or other stable watercourses that convey runoff without causing erosion.

4. Where erosion is liable to occur, the operator shall construct diversion ditches, that in the opinion of the Approving Authority are adequate to ensure that the lands to be disturbed are protected from erosion.

5. (1) The operator shall ensure that drainage from disturbed lands, under normally prevailing seasonal climatic conditions, shall only be discharged in accordance with Alberta Environment's surface water wuality objectives or other methods prescribed by the Approving Authority to a receiving stream or other watercourse described in the Guidelines or prescribed method.

(2) When directed by the Approving Authority, the operator shall cause to be designed and constructed any settling ponds or other facilities that may be necessary to settle sediments from run-off that is equivalent to at least a ten year flood condition, to the extent that the total suspended solids content in any water discharged from the settling pond or other facilities will not exceed the concentration permitted by the Approving Authority.

Conservation of Materials for Reclamation

1. (1) Where, before the approved land disturbance, soil horizons on the lands to be disturbed are sufficiently well developed to support plant growth or in the opinion of the Approving Authority to be capable of supporting plant growth, the soil horizons hsall be selectively removed in the manner prescribed by the Approving Authority.

(2) Whenever it is necessary to store soil and other surficial material suitable for reclamation, the geotechnical foundation of areas used by the operator for storage shall be stable and the storage areas shall be protected from wind and water erosion.

(3) The operator shall use all soil and surficial material suitable for reclamation to perform the reclamation in the manner prescribed by the Approving Authority.

Backfilling and Recontouring

1. Any material that is toxic to plants or animals, or in the opinion of the Approving Authority may be toxic to plants or animals, shall be disposed of by the operator by burial below the root zone or in the manner described in the Approval for the disturbance or as may otherwise be prescribed by the Approving Authority, at a location where groundwater quality will not be adversely affected.

2. Highwalls, footwall, embankments and slopes shall be reduced or backfilled and graded as closely as possible to the same contours as the contours that existed before the disturbance and to a slope not greater than 2:1 unless the Approving Authority otherwise prescribes.

3. All excavations shall be filled and reclaimed to the contours prescribed in the applicable Approval or as determined by the Approving Authority in consultation with the owner, having regard to the prescribed post-disturbance land use.

4. (1) Where the prescribed post-disturbance land use is agricultural production, the operator shall grade the land

(a) as closely to the same contours as the contours that existed before the disturbance, and

(b) to a slope, wherever possible, not greater than 5:1; but all contouring shall allow for soil subsidence and erosion control.

(2) Where the prescribed post-distrubance land use is a use requiring irrigation, the operator shall grade the land use as closely to the same contours and slope as the contours and slope that existed before the approved surface disturbance, or to contours and slope that are equivalent to the contours and slope of irrigated lands in areas adjacent to the reclaimed lands.

(3) Where the prescribed post-disturbance land use is commercial timber production, the operator shall grade the land

(a) as closely to the same contours as the contours that existed before the approved surface disturbance, and

(b) to a slope, wherever possible, not greater than 3.5:1.

(4) Where the prescribed post-disturbance land use is a use other than agricultural or commercial timber production, the contours and maximum slopes of the reclaimed lands shall not exceed equivalent contours and maximum slopes on lands in areas adjacent to the disturbed lands or as otherwise prescribed by the Approving Authority.

Restructuring of the Root Zone

1. (1) Where the prescribed post-disturbance land use is agricultural production, the operator shall place root zone soil, having a depth that is sufficient to support agricultural plant growth, in proper sequence, on the surface of the reclaimed lands.

(2) Where the prescribed post-disturbance land use is a use other than agricultural production, the operator shall place soil or other plant-supporting materials on the surface of the reclaimed lands so that a restructured soil, having a depth, and chemical and physical characteristics suitable and sufficient for supporting plant life, is available to achieve the prscribed post-disturbance land use.

(3) Where sufficient soil or other surficial plant-supporting materials is available, the operator shall provide a root zone having a depth at least equal to the depth of the rooting zone of the plants that are being used in the reclamation process.

Revegetation

1. When required by the Approving Authority, the operator shall, as soon as practicable following placement on the lands of soil or other surficial plant-supporting material, seed or plant on the reclaimed lands, suitable plant species in the manner and to the extent prescribed by the Approving Authority in consultation with the owner.

2. (1) Where the prescribed post-disturbance land use is the establishment of permanent forest vegetation, the operator shall establish an initial vegetative cover that will not inhibit forestation that is achieved through the growth of approved tree species, through the invasion of native tree species, or through other forestation techniques or methods.

(2) The operator is responsible for the establishment of such additional idigenous plant species as may be necessary to achieve a self-sustaining forest plant community.

3. Where the prescribed post-disturbance land use is the establishment of permanent forest vegetation for commercial timber production, the operator is responsible for the establishment, in a manner prescribed by the Alberta Forest Service Regeneration Survey Manual, of a minimum of 320 established seedling trees as defined in the Timber Management Regulations, per acre of commercial tree species satisfactory to the Approving Authority.

4. Where the prescribed post-disturbance land use is the establishment of permanent vegetation suitable for wildlife habitat, the operator is responsible for the establishment of various species and numbers of trees, grasses, forbs and shrubs of a density and composition which will provide food and cover for wildlife, consistent with the ecological zone of the region and satisfactory to the Approving Authority.

Restoration or Services and Utilities

1. All survey monuments established under The Alberta Surveys Act and all roads and public utilities established before the approved surface disturbance shall be maintained or replaced by the operator as prescribed by law and by the Approving Authority.

2. All domestic, municipal, irrigation and other agricultural water supply systems established before the approved surface disturbance shall be maintained or re-established by the operator to provide a level of service at least equivalent to that which existed prior to disturbance.

3. Access roads and haul roads that in the opinion of the Approving Authority, in consultation with the owner, are no longer necessary, shall be reclaimed by the operator in the manner prescribed by the Approving Authority.

Aesthetics and Safety

1. The operator shall leave the reclaimed lands in a state free of unnecessary structures and equipment, and shall landscape the lands so that they are aesthetically satisfactory to the Approving Authority.

2. The operator shall leave the reclaimed lands in a safe condition, free of

   (a) All hazards including any open excavations, unstable high-walls, footwalls, embankments or slopes;

   (b) any hazardous substances including explosives and toxic or radioactive materials, and

   (c) any garbage, debris or other waste materials.

1. (1) Where the prescribed post-disturbance land use is agricultural production, the operator shall remain responsible for the maintenance of the reclaimed land during the period of time that is required to demonstrate that the agricultural productivity of any soil placed by the operator on the reclaimed lands is comparable

(a) to the agricultural productivity that existed prior to the surface disturbance, or

(b) where the pre-disturbance use of the land was not agricultural production, to such other productivity standard as the Approving Authority may prescribe.

(2) Where the prescribed post-disturbance land use is a use other than agricultural production, the operator shall remain responsible for the maintenance of the reclaimed lands until

(a) the soil surface has been stabilized and the composition, density, growth and vigor of vegetation established by the operator is comparable to the composition, density growth and vigor of vegetation that existed before the surface disturbance, or

(b) the condition of the land is comparable to the condition of other similar lands that have been reclaimed in a manner satisfactory to the Approving Authority.

(c) 320 established seedling trees per acre are growing on the site without assistance when the prescribed post-disturbance land use is commercial timber production.

APPENDIX V.

DESCRIPTION OF LAND RESOURCE ZONES

LAND RESOURCE ZONES	PHYSIOGRAPHIC FEATURES	VEGETATION[1] (In order of dominance)	SOIL CLIMATE[2] (In order of dominance)	MAJOR LAND USE ACTIVITIES	MAJOR MINE COMMODITIES
I.1 Northern Cordilleran	Mountains highlands foothills	1. Tundra: alpine sedges, grasses, shrubs. 2. Open Woodland: shrubs, grasses patches of needleleaf trees. 3. Boreal: needleleaf trees with some broadleaf trees, and barren patches.	1. Very cold subarctic. 2. Very cold subarctic to cold Cryoboreal (complex of vertical zonation and aspect.	Hunting, trapping, mining, tourism, outdoor recreation, forestry (minor).	Copper, gold, Tungsten, Silver lead, zinc, cadmium asbestos, coal.
	Plateaux, basins valleys	1. Boreal: as above. 2. Tundra: as above. 3. Open woodland: as above.	Wide spread permafrost.		
I.2 Southern Cordilleran	Mountains highlands foothills	1. Subalpine Forest: needleleaf trees often with an open distribution.	1. Cold Cryoboreal. 2. Very cold Subarctic.	Forestry, mining, agriculture, tourism, outdoor recreation, fishing.	Coal, barite, gypsum, lead, zinc, silver, gold, copper molybdenum, iron, antimony, cadmium.
		2. Pacific Coastal and Interior 'Wet Belt' (Columbia) Forest: needleleaf trees.	Cold to moderately cold. Cryoboreal (Maritime influence).		
		3. Tundra: alpine sedges, grasses, shrubs.	Very cold Subarctic to cold Cryoboreal		
	Plateaux, basins, valleys	1. Plateau. Mountain Forest: needleleaf trees with some boreal broadleaf trees, and grassland in valleys.	1. Cold to moderately cold Cryboreal. 2. Cool Boreal.		
		2. Subalpine forest: as above.	Cold Cryoboreal		
		3. Parkland: needleleaf trees with patches of grassland.	Cool to moderately cool Boreal. (Semi-arid areas)		
		4. Grassland: low grass	Moderately cool Boreal to mild Mesic. (Arid areas).		

Sources: (1) Dep. Energy, Mines and Resources, 1974*b*; (2) Clayton *et al.*, 1977.

APPENDIX V.

DESCRIPTION OF LAND RESOURCE ZONES *Cont'd*

LAND RESOURCE ZONES	PHYSIOGRAPHIC FEATURES	VEGETATION[1] (In order of pre-dominance)	SOIL CLIMATE[2] (In order of pre-dominance)	MAJOR LAND USE ACTIVITIES	MAJOR MINE COMMODITIES
II.1 Northern Interior Plains (MacKenzie)	Plains	1. Open woodland: lichen floor with scattered needleleaf trees, broadleaf shrubs.	Very cold Subarctic (north of Great Slave Lake)	Fishing, hunting, trapping, mining, forestry.	Zinc, lead, oil and gas
		2. Boreal forest: needleleaf with some broadleaf.	Cold Cryoboreal to very cold Subarctic (west and south of Lake Athabasca).		
		3. Tundra: Arctic dwarf shrubs, sedges, lichen - heath.	Extremely cold Arctic (north of Great Bear Lake)		
	Lowlands, plateaux	Boreal: needleleaf trees with some broadleaf, and western coniferous species.	1. Cold Cryoboreal. 2. Very cold Subarctic.		
II.2 Central Interior Plains (Peace Athabasca Rivers)	Plateaux	1. Boreal: needleleaf with some boreal broadleaf (to the east). Boreal: needleleaf with western coniferous species (to the west).	Cold Cryoboreal	Forestry, mining, agriculture, fishing, trapping, tourism, outdoor recreation.	Coal, oil sands, sand, gravel.
	Lowlands, plains	2. Parkland: broadleaf trees with patches of grassland.			
II.3 Southern Interior Plains	Plains	1. Grassland.	Cool to moderately cool. Boreal (semi-arid).	Agriculture, mining, oil and gas, fishing, outdoor recreation.	Coal, potash, sodium, sulphate, salt, bentonite, barite, silica, gypsum, clay, sand, gravel, stone.
		2. Parkland: broadleaf trees and patches of grassland.	Moderately cold Cryoboreal to cool Boreal. (Some arid areas).		
		3. Boreal Forest (Manitoba, Saskatchewan): Needleleaf trees with some broadleaf trees, and patches of bogs and swamps. (Alberta): Needleleaf with some Boreal broadleaf trees.	Cold to moderately cold Cryoboreal.		

APPENDIX V.

DESCRIPTION OF LAND RESOURCE ZONES *Cont'd*

LAND RESOURCE ZONES	PHYSIOGRAPHIC FEATURES	VEGETATION[1] (In order of pre-dominance)	SOIL CLIMATE[2] (In order of pre-dominance)	MAJOR LAND USE ACTIVITIES	MAJOR MINE COMMODITIES
III Arctic Archipelago	Mountains plateaux, uplands, lowlands	Tundra: rock desert and arctic stony lichen heath.	Extremely cold Arctic. Continuous permafrost. 2. Very cold subarctic to cold Cryoboreal (complex of vertical zonation and aspect).	Mining (minor).	Lead, zinc, copper, silver.
IV.1 Canadian Shield Southern	Uplands, highlands	1. Boreal: needleleaf in the north; needleleaf with some broadleaf, to the south.	Cold Cryoboreal to very cold Subarctic.	Mining, forestry, tourism, fishing, trapping, outdoor recreation, agriculture.	Copper, zinc, gold, silver, cadmium, selenium, tellurium, iron, nickel, titanium, talc, nephaline, seyenite, uranium, cobalt, serpentine.
		2. Southern mixed forest: broadleaf with needleleaf.	Moderately cold Cryoboreal to cool Boreal		
IV.2 Canadian Shield central uplands and plateaux	Plateaux (Quebec)	1. Open woodland: lichen floor and scattered needleleaf shrubs. 2. Boreal: needleleaf trees, patches of needleleaf trees.	Cold Cryoboreal to very cold Subarctic. Discontinuous permafrost.	Mining, fishing, trapping, forestry, tourism, outdoor recreation, forestry (minor).	Iron, silver, copper, zinc, lead, gold, uranium, cobalt, cadmium, selenium, tellurium
	Uplands (Manitoba, Saskatchewan, N.W.T.) Plateaux, basins valleys	1. Boreal: needleleaf with shrubs and barren patches. 2. Open woodland: lichen floor, heath, shrubs, scattered needleleaf trees.	Very cold Subarctic to cold Cryoboreal. Widespread permafrost.		
IV.3 Canadian Shield (northern Arctic)	Mountains, plateaux, uplands	Tundra: Arctic dwarf shrubs: stony sedges - lichen heath.	Extremely cold Arctic Permafrost.	Fishing, hunting, trapping, mining.	Asbestos.

APPENDIX V.

DESCRIPTION OF LAND RESOURCE ZONES *Cont'd*

LAND RESOURCE ZONES	PHYSIOGRAPHIC FEATURES	VEGETATION[1] (In order of pre-dominance)	SOIL CLIMATE[2] (In order of pre-dominance)	MAJOR LAND USE ACTIVITIES	MAJOR MINE COMMODITIES
V. Hudson Bay Lowlands	Lowland	1. Bogs - Organic terrain: small lakes, moss and sedge covered floor, and strings of needleleaf trees. 2. Tundra: dwarf shrubs - sedges, lichen - heath (along Hudson Bay coastline).	1. Very cold Subarctic. 2. Very cold Subarctic to cold Cryoboreal (west of James Bay). Discontinuous permafrost.	Trapping, hunting.	
VI.1 St. Lawrence Lowland - Lower Great Lakes	Lowland, plains	1. Southeastern Mixed Forest: broadleaf trees with needleleaf trees.	Moderately cool Boreal to mild Mesic.	Agriculture, fishing, manufacturing, tourism, outdoor recreation.	Gypsum, salt, sand, gravel, crushed stone.
		2. Southern Broadleaf forest.	Mild to moderately warm Mesic.		
VI.2 Central St. Lawrence lowland	lowland, plains.	Southeastern Mixed Forest: broadleaf trees with needleleaf trees.	Moderately cool Boreal to mild Mesic.	Agriculture, fishing, manufacturing, tourism, outdoor recreation.	Magnesium, calcium, silica, magnesite, magnesitic dolomite, sand, gravel, crushed stone.
VII Appalachian	Mountains highlands	1. Boreal: needleleaf. 2. Southeastern Mixed Forest: broadleaf with needleleaf (Quebec, Nova Scotia, New Brunswick and Prince Edward Island). 3. Open woodland: (Newfoundland).	1. Moderately cold Cryoboreal to moderately cool Boreal. 2. Cold Cryoboreal (Newfoundland).	Forestry, tourism, outdoor recreation, fishing, mining, agriculture.	Coal, asbestos, lead, zinc, copper, molybdenum, silver, gold, cadmium, potash.
	Uplands	1. Boreal: broadleaf and needleleaf. 2. Open woodland: shrubby needleaf trees, patches of heath and barren (Newfoundland)	1. Moderately cold Cryoboreal (Newfoundland). 2. Moderately cool Boreal to mild Mesic (Nova Scotia) 3. Cool Boreal (New Brunswick).		
	Plains, lowlands.	Boreal: needleleaf and broadleaf.	Cool to modereately cool Boreal.		

APPENDIX VI.

ESTIMATED LAND DISTURBANCES BY MINING IN CANADA: 1970, 1975
(National Advisory Committee on Mining and Metallurgical Research)

Type of Mine	1970		1975	
	Disturbed	Reclaimed	Disturbed	Reclaimed
			(hectares)	
Copper, Nickel	10,117	567	11,412	1,457
Lead, Zinc, Silver, Cobalt	1,619	-	1,821	-
Uranium	No data	36	No data	202
Gold	1,740	-	No increase	405
Molybdenum, Columbium Tantalum, Tungsten	445	34	1,665	202
Iron Ore	18,211	-	No increase	-
Coal	14,164	810	15,783	2,428-3,642
Asbestos	2,833	-	No increase	20
Potash	1,620	-	2,428	-

Source: Rabbitts *et al.*, 1971.

APPENDIX VII.

LAND DISTURBANCES EFFECTED BY MINING IN CANADA: by Province, Territory and Land Type[1] (Area in Hectares)

PROVINCE OR TERRITORY	OPEN PIT	OVERBURDEN	SLURRY PONDRY	TAILINGS	WASTE ROCK	SLAG	TOTAL	VEGETATIVE COVER*
Newfoundland	350	1,281	141	580	182		2,534	19
Nova Scotia	3	716	29	70	192		1,010	120
New Brunswick	23	4,537	92	344	101		5,097	1,681
Quebec	641	1,330	200	4,078	1,988	12	8,249	601
Ontario	190	1,107	1,676	6,125	1,107	261	10,466	758
Manitoba	15	257	216	641	129		1,258	14
Saskatchewan	4	3,403	188	1,994	63		5,652	1,706
Alberta	7	3,436	29	315	155		3,942	1,313
British Columbia	147	3,241	182	2,647	2,868	10	9,095	722
Northwest Territories		347	2	518	268		1,135	10
Yukon	54	2,340	22	166	104		2,686	256
CANADA	1,434	21,995	2,777	17,478	7,157	283	51,124	7,200

* Vegetative cover includes all areas of residual natural cover, natural re-inversion by grasses, shrubs and trees, and revegetation on reclaimed areas. No distinction was made between these categories. Vegetative cover ranged from heavy, to moderate, to poor, the majority falling in the moderate to poor range.

Source: Murray, 1977b.

APPENDIX VIII.

COMPARISON OF VARIOUS STUDIES ON LAND DISTURBANCE AND RECLAMATION IN THE MINING INDUSTRY OF CANADA

	CANMET (c) Inventory (1977b)	ENVIRONMENT (a) Canada (1972)	RABBITT's (c) etal., (1970)	LANDS DIRECTORATE (b) Current Review (1980)
Total Land Disturbed	51,124 ha	18,602 ha	52,610 ha (1975 estimate) 59,895 ha	233,968 ha
Total Land Reclaimed	7,200 ha (includes natural re-vegetation)	893 ha	1,447 ha 4,715 - 6,056 ha (1975 estimate)	13,733 ha (d)
No. of Mine Sites Investigated	705	102	77	705 plus
No. of Companies Involved in Some Form of Reclamation Activity	105	26	30-38	116

(a) Study did not include potash, coal, gold, asbestos, gypsum mines, or sand and gravel pits.
(b) Included sand and gravel pits, oil sands.
(c) Study did not include sand and gravel pits or oil sands.
(d) Does not include sand and gravel pits, quarries in reclaimed figures.

Sources: Rabbitts _et al._, 1971; Environment Canada, 1972; Murray, 1977_b_.

APPENDIX IX

DATA SOURCES USED TO COMPILE TABLE 28. LAND AREA DISTURBED BY MINING WASTES AND TABLE 34. ESTIMATED AREA OF LAND DISTURBANCES RECLAIMED

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